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The two-year research program, "Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California," explores how urban growth and change in the rapidly developing area located between San Diego and Los Angeles might influence the biodiversity of the area. The study was conducted by a team of investigators from the Harvard University Graduate School of Design, Utah State University, the National Biological Service, the USDA Forest Service, The Nature Conservancy, and the Biodiversity Research Consortium, with the cooperation of the two relevant regional agencies, the San Diego Association of Governments and the Southern California Association of Governments, and Marine Corps Base Camp Pendleton.

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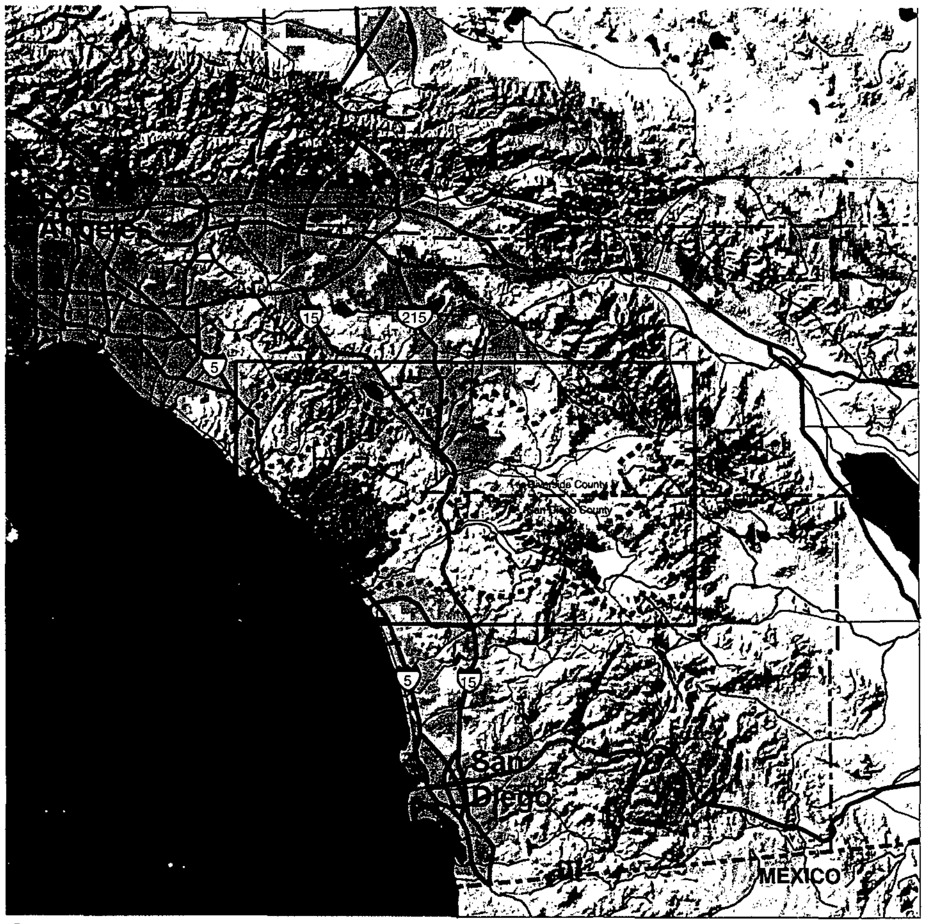
BIODIVERSITY AND LANDSCAPE PLANNING:

ALTERNATIVE FUTURES FOR THE REGION OF CAMP PENDLETON, CALIFORNIA



Camp Pendleton, California Context

MCB Camp Pendleton | Urban | National Forests | Water | Interstate Highways | Major Roads | Watershed Boundaries | County Boundary

BIODIVERSITY AND LANDSCAPE PLANNING:

ALTERNATIVE FUTURES FOR THE REGION OF CAMP PENDLETON, CALIFORNIA

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This study explores how urban growth and change in the rapidly developing region between San Diego and Los Angeles might influence the biodiversity of the area. The research was supported by the Strategic Environmental Research and Development Program, a joint program of the U.S. Department of Defense, the U.S. Department of Energy, and the U.S. Environmental Protection Agency, through a grant to the Western Ecology Division of the EPA's National Health and Environmental Effects Research Laboratory, and the U.S. Department of Agriculture Forest Service Pacific Northwest Research Station.

The study was conducted by a team of investigators from the Harvard University Graduate School of Design, Utah State University, the National Biological Service, the USDA Forest Service, The Nature Conservancy, and the Biodiversity Research Consortium, with the cooperation of the two relevant regional planning agencies, the San Diego Association of Governments and the Southern California Association of Governments, and Marine Corps Base Camp Pendleton. There is, however, no contractual obligation or consultative relationship between the investigators and any sponsoring groups or governing jurisdictions. The information herein is believed to be reliable, but the investigators and their institutions do not warrant its completeness or accuracy. Opinions and estimates constitute judgments of the research team.

The sole purpose of this research publication is educational: to provide information regarding issues, strategic planning options, and possible consequences related to biodiversity to the many stakeholders and jurisdictions whose actions that will influence the region's future biodiversity.

Cambridge, MA
Logan, UT
Corvallis, OR
Temecula, CA
1996

Summary

The two-year research program, "Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California," explores how urban growth and change in the rapidly developing area located between San Diego and Los Angeles might influence the biodiversity of the area. The study was conducted by a team of investigators from the Harvard University Graduate School of Design, Utah State University, the National Biological Service, the USDA Forest Service, The Nature Conservancy and the Biodiversity Research Consortium, with the cooperation of the two relevant regional agencies, the San Diego Association of Governments (SANDAG) and the Southern California Association of Governments (SCAG), and Marine Corps Base (MCB) Camp Pendleton. The research was supported by the Strategic Environmental Research and Development Program (SERDP), a joint program of the U.S. Department of Defense, the U.S. Department of Energy, and the U.S. Environmental Protection Agency (EPA), through a grant to the Western Ecology Division of the EPA's National Health and Environmental Effects Research Laboratory, and the USDA Forest Service Pacific Northwest Research Station.

The study region is an 80 kilometer x 134 kilometer rectangle that encompasses the five major river drainage basins directly influencing Camp Pendleton: San Juan, San Mateo, San Onofre, Santa Margarita, and San Luis Rey. The research strategy is based on the hypothesis that the major stressors causing biodiversity change are related to urbanization. As population increases and development spreads, habitat is lost due to grading, paving, ornamental landscaping, and other human activities. There are also indirect, secondary, and cumulative effects on vegetation by development through hydrologic and fire influences. These affect habitat and, ultimately, biodiversity.

A computer-based Geographic Information System was developed to describe the region. Analytical models use the digital data to evaluate the complex dynamic processes at work in the very large study area and the possible impacts on biodiversity resulting from changes in land use.

Future change is studied at four scales: several restoration projects, a subdivision, a third order watershed, and the region as a whole. Regional change is simulated via six alternative projections of development to the year 2010 and to subsequent "build-out." The first scenario is based upon the current local and regional plans as summarized by the Southern California Association of Governments, the San Diego Association of Govenments, and those of Camp Pendleton. Five alternative scenarios provide a method to explore and compare the impacts of different land use and development policies relating to biodiversity. Alternative #1 illustrates what may be considered the dominant spread pattern of low-density growth. Alternative #2 also follows the spread pattern, but introduces a conservation strategy in the year 2010. Alternative #3 proposes private conservation of biodiversity by encouraging large-lot ownership adjacent to and encompassing important habitat areas. Alternative #4, focuses on multi-centers of development and new communities. Lastly, Alternative #5 concentrates growth in a single new city. All alternatives accommodate the population forecast for the region.

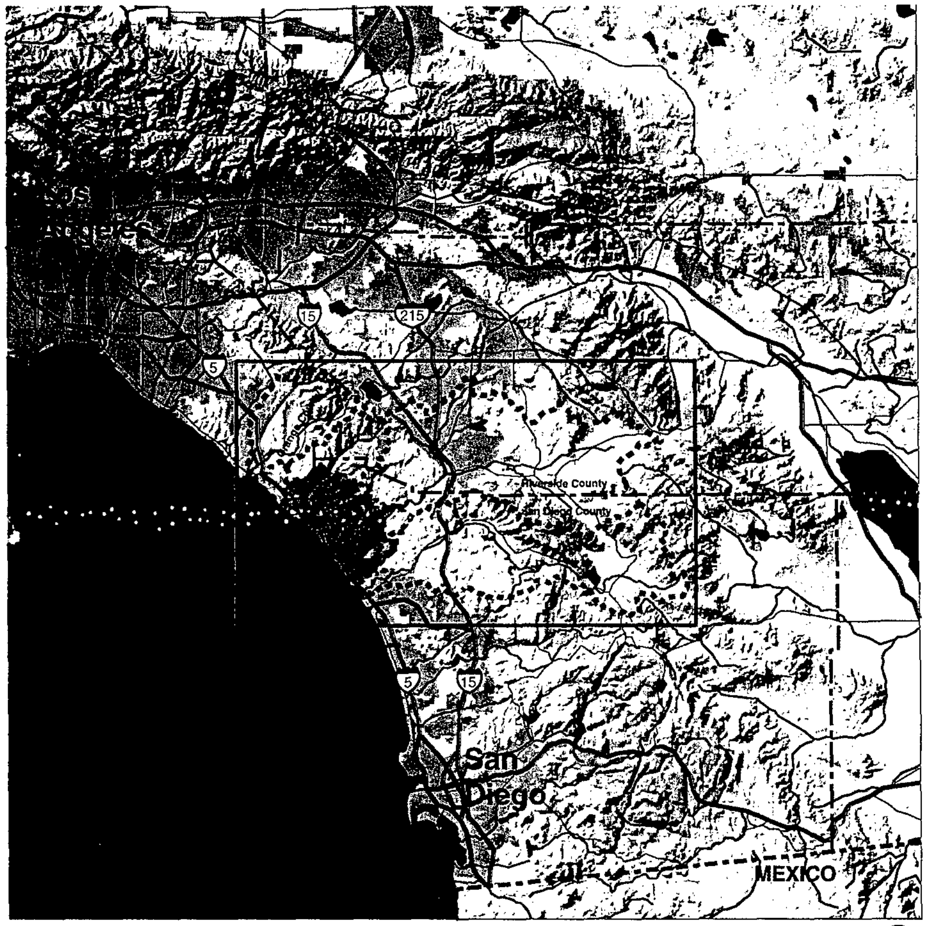
A set of process models is used to assess each alternative. The soils models evaluate the agricultural productivity of the area's soils. The hydrology models predict the 25-year storm hydrographs for each of the rivers and their subwatersheds, flooding heights and water discharge, and resultant soil moisture. The fire models assess both the need for fire in maintaining vegetation habitat, and the risks of fire and fire suppression. The visual model assesses scenic preferences for the region's landscape. Biodiversity is assessed in three ways: a landscape ecological pattern model; ten selected single species potential habitat models; and a species richness model.

The evaluations of the alternatives may be used by stakeholders, including MCB Camp Pendleton, to assess the desirability of the policies which generated them or to devise and compare additional development scenarios and conservation strategies.

While the research team is not making specific recommendations as part of this program, we do hope to increase understanding of the risks and benefits of a range of alternatives for the Camp Pendleton region and to provide tools and techniques which may be helpful in managing the processes of urbanization and landscape change for its several political units and its many stakeholders.

Contents

Figure 1

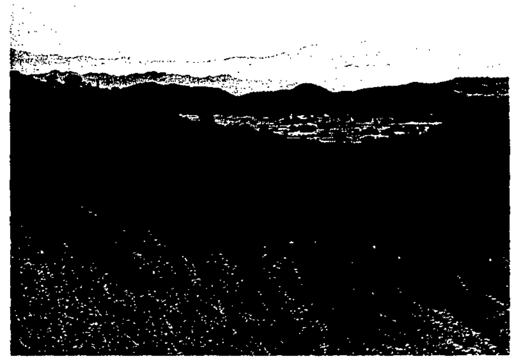


Camp Pendleton, California Context

MCB Camp Pendleton | Urban | National Parks | Water | Interstate Highways | Major Roads | Watershed Boundaries | County Boundary

Biodiversity and the Need for Landscape Planning

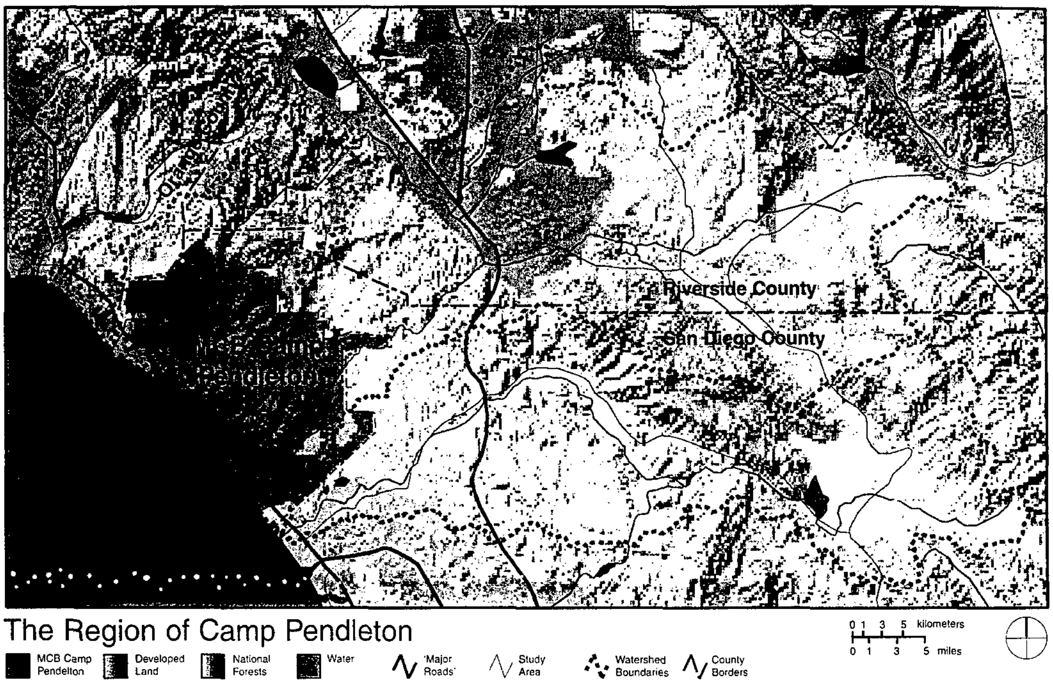
Figure 1



Biodiversity, in the simplest terms, is the pattern and variety of life and its processes. It is a manifestation of genetic diversity and is the result of the evolutionary adaptation of plants and animals to environmental conditions. As such, relationships between type and quality of habitat and species diversity are tightly coupled. Recently, the U.S. Environmental Protection Agency's Science Advisory Board identified habitat modification and loss of species diversity at the highest level of environmental risk to the country (U.S. EPA, 1990). The Board expressed the view that natural habitats are under severe and widespread stress, primarily from the loss, alteration, and degradation of natural ecosystems resulting from direct and indirect human activities. Yet, while the unprecedented rate of decline in worldwide biological diversity has become a major public concern, few studies have attempted to systematically and quantitatively assess risks to biodiversity at the regional landscape scale. The intent of this project, "Biodiversity and Landscape Planning: Alternative Futures for the Region of Camp Pendleton, California," is to examine the connections between urban, suburban, and rural development and the consequent stresses on native habitats and biodiversity.

While the initiative of this study stems from a research question, the issues of biodiversity are not limited to scientific inquiry. The breadth of social values and range of physical needs associated with biodiversity, and thus the impetus to conserve biodiversity, are best described by E. O. Wilson and Paul Ehrlich, who provide three observations. "The first [reason] is ethical and esthetic. Because *Homo sapiens* is the dominant species on Earth, we and many others think that people have an absolute moral responsibility to protect what are our only known living companions in the universe. Human responsibility in this respect is deep, beyond measure, beyond conventional science for the moment, but urgent nonetheless. The second reason is that humanity has already obtained enormous direct economic benefits from biodiversity in the form of foods, medicines, and industrial products, and has the potential for gaining many more. Biodiversity is a precious "genetic library" maintained by natural ecosystems. But the potential of the library to supply such benefits has barely been tapped. The third reason, perhaps the most poorly evaluated to date, is the array of essential services provided by natural ecosystems, of which diverse species are the key working parts." (Ehrlich and Wilson, 1991)

In recognition that research on the loss of biological diversity can be addressed effectively only through the cooperation of interested parties, the inter-agency Biodiversity Research Consortium (BRC) was formed to develop analytical methods for assessing and managing risks to biodiversity. Current membership in the consortium includes the U.S. Environmental Protection Agency (EPA), U.S. Department of the Interior (USDI) through the National Biological Service, the Geological Survey, and the Bureau of Land Management, U.S. Department of Agriculture (USDA) Forest Service, U.S. Department of Defense (DoD), the Smithsonian Institution, and The Nature Conservancy (TNC). In addition, a number of academic institutions participate as research collaborators, including Harvard and Utah State Universities. The BRC conducts biodiversity-related research at a hierarchical set of spatial scales. This research on the area surrounding Marine Corp Base (MCB) Camp Pendleton is one of the pilot investigations at the regional or landscape scale, and was organized



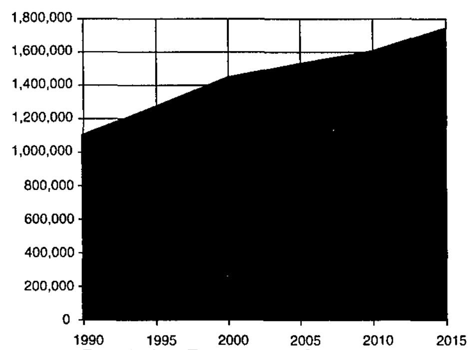
The Region of Camp Pendleton

Figure 2

to explore how urban and suburban growth and change which is forecast and planned in the rapidly developing area located between San Diego and Los Angeles will influence biodiversity. Other BRC pilot studies include state-scale analyses of Oregon and Pennsylvania and a national-scale analysis of bird species diversity.

The location of the region of Camp Pendleton is shown in figure 1. Recognizing that land-use changes and the hydrologic regimes that influence biodiversity occur over a large area, the study area has been defined as the five watersheds of the rivers that flow through or are immediately adjacent to Camp Pendleton. These watersheds are the San Juan, the San Mateo, the San Onofre, the Santa Margarita, and the San Luis Rey. It should be noted that while the definition of the study area in terms of physical terrain is valuable for understanding the natural processes of the area, it does not easily adapt to jurisdictional boundaries. As shown in figure 2, the study area straddles parts of Orange, Riverside, and San Diego Counties.

The region is one of the country's most desirable places to live and work, and it continues to grow and develop. Its population in 1990 was about 1.1 million, as shown in figure 3. The regional planning agencies forecast that by 2010 the population will grow to 1.6 million, and it is expected to continue to grow beyond that date. The effects on biodiversity will depend on several factors including where and how people build homes, where new industry will be located, where new infrastructure will be built to support urbanization, and whether and where land will be conserved.



Population Forecast by County

Figure 3

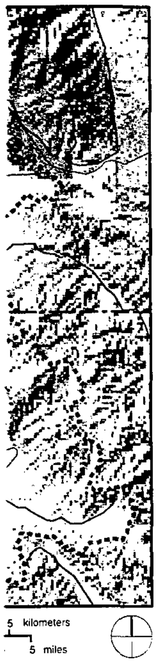


Figure 2

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Figure 3

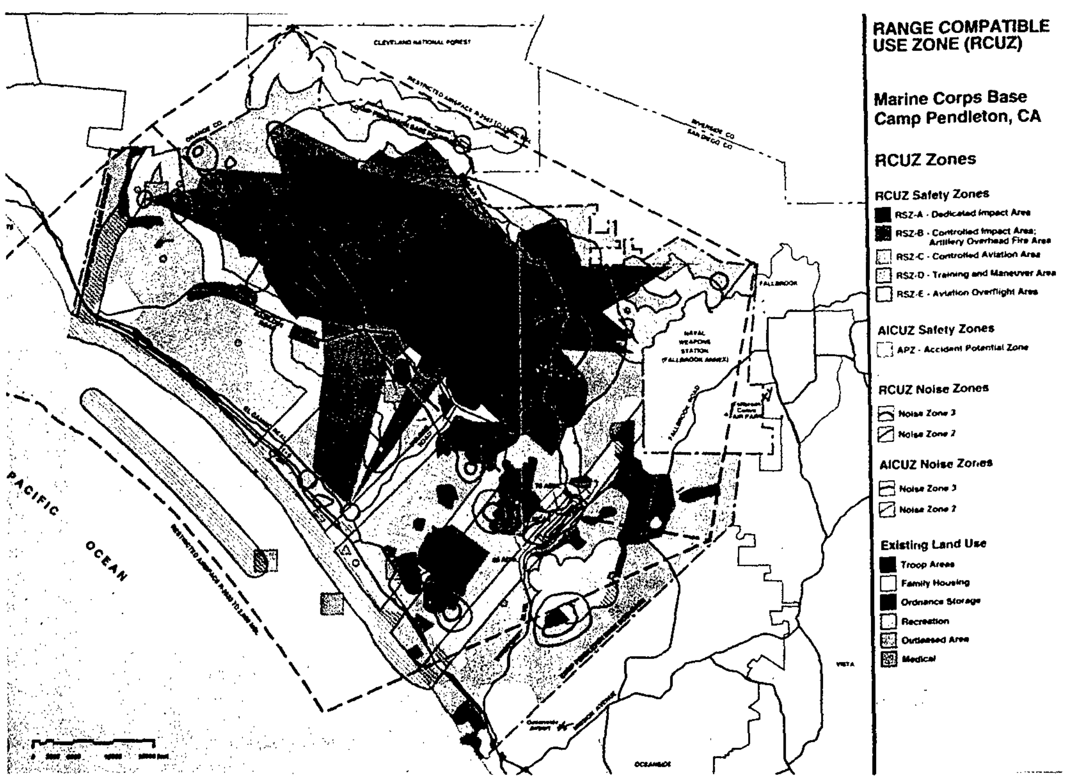
The study area is one of the most biologically diverse environments in the continental United States. It supports a variety of habitat types including coastal lagoons and estuaries, coastal scrub areas, maritime-influenced chaparral and scrub communities, oak woodlands, coniferous mountain areas, and dry, hot, sparsely vegetated deserts. Each of these supports a unique range of animal species. Within the region are over 200 plants and animals listed by federal or state agencies as endangered, threatened, or rare. These include the least Bell's vireo, the coastal cactus wren, and the California gnatcatcher. In addition, a number of plants and animals are of local concern due to declining populations, such as the California cougar.

The landscape within MCB Camp Pendleton, the largest unbuilt portion of land on the southern California coastline, is central to maintaining the long term biodiversity of the area. The base's 49,857 hectares include diverse habitats of coastal tidal zone, sensitive riparian vegetation, steep hillsides covered with sage and chaparral, fire prone grasslands, and mature stands of oak forest. Camp Pendleton's twenty-seven kilometer coastline remains the only large habitat area for marine birds in southern California. Its northeast boundary abuts the San Mateo Wilderness Area of the Cleveland National Forest, and it is close to the Santa Rosa Plateau Ecological Reserve, which maintains the largest remaining native California bunchgrass grassland. As a result, Camp Pendleton plays a key role in the connectivity of the region's ecosystems.

While Camp Pendleton is largely unbuilt, it is not undeveloped. The primary mission of the base is the training of Marines and, as seen in figure 4, its entire area is administered for diverse functions toward that goal. Of unique importance, Camp Pendleton is the only facility on the west coast where amphibious assault maneuvers can be practiced. Moreover, the Marines expect that training activities on the base will be expanded and intensified as units relocate from decommissioned bases to Camp Pendleton. (USMC, 1991). The combination of the increasing development pressures, both on the base and in the surrounding region, and high biodiversity creates a setting where natural resource issues come into sharp focus.

The situation of a major military facility becoming increasingly interdependent with its surrounding area is not unique to this study area. As activities on some bases intensify due in part to base realignments and closures elsewhere, and development pressures in their regions increase, potential conflicts between the military mission and local concerns can bring issues of land use and land management to the fore. The management of biodiversity is one of these issues. The costs of potential conflicts and the benefits of their resolution are of significance, in this case not only for MCB Camp Pendleton and its region, but for the nation.

Figure 4



Readers should consider some caveats:

The investigators are conducting independent research and not providing consulting or planning services to any regional stakeholders, the Southern California Association of Governments (SCAG), the San Diego Association of Governments (SANDAG), or MCB Camp Pendleton.

The investigators have made assumptions based upon publicly available documents, without having met widely with private stakeholders or local government.

The research models are based on existing and publicly available data. The investigators cannot be held responsible for data errors or their implications.

Private property boundaries and local governmental jurisdictions are not being considered in the alternative futures except as they are identified in published regional plans.

The research has a limited scope with a selective focus on biodiversity and related aspects of environmental planning. The research findings, including the alternative future scenarios and their comparative evaluations, are not intended to be comprehensive analyses of the region.

In summary, there are several reasons for the research group to have selected the region of Camp Pendleton for study. First, it has some of the highest biodiversity in the United States. Second, it is experiencing dramatic growth and will have to manage increasing development pressures. Third, a considerable amount of information about the area has been compiled, but had not yet been synthesized across county boundaries for the regional management of biodiversity. Fourth, there is still time to make a difference.

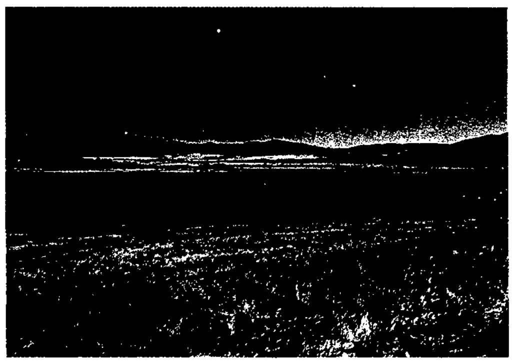
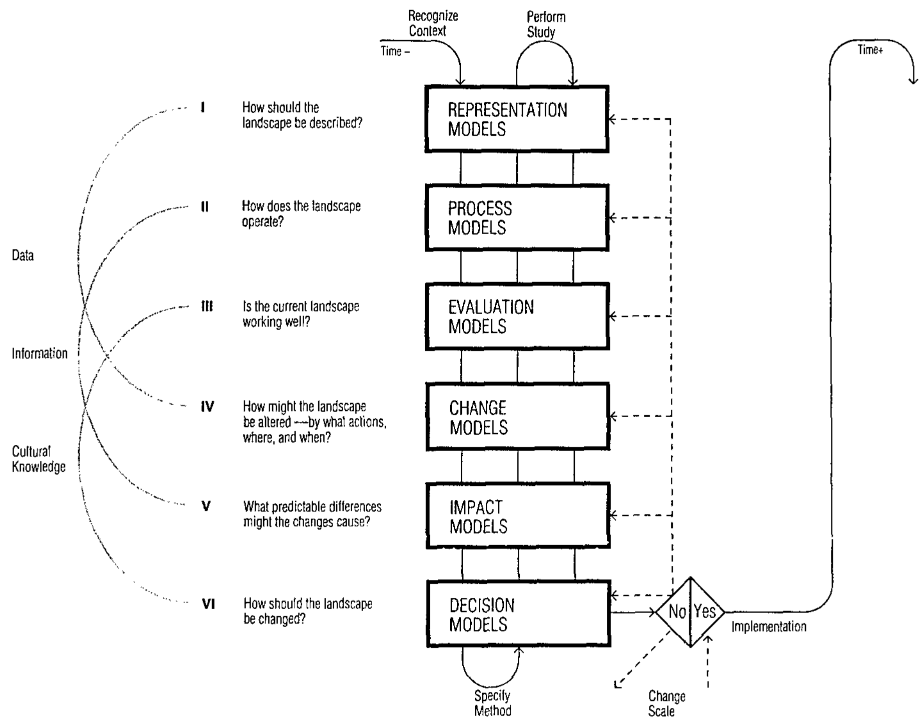


Figure 5



The research was organized to answer six questions of method following the framework for landscape planning outlined by Carl Steinitz (1990, 1993). Over the course of the study, each set of questions was asked three times: the first time to define the context and scope of the research, the second time to specify the methods of study, and the third time to carry the project forward to a set of conclusions. Figure 5 illustrates the generalized framework and figure 6 shows how the component data and models of this research program are linked via the framework.

The six questions, listed in the usual order for defining the context of a landscape planning study, are:

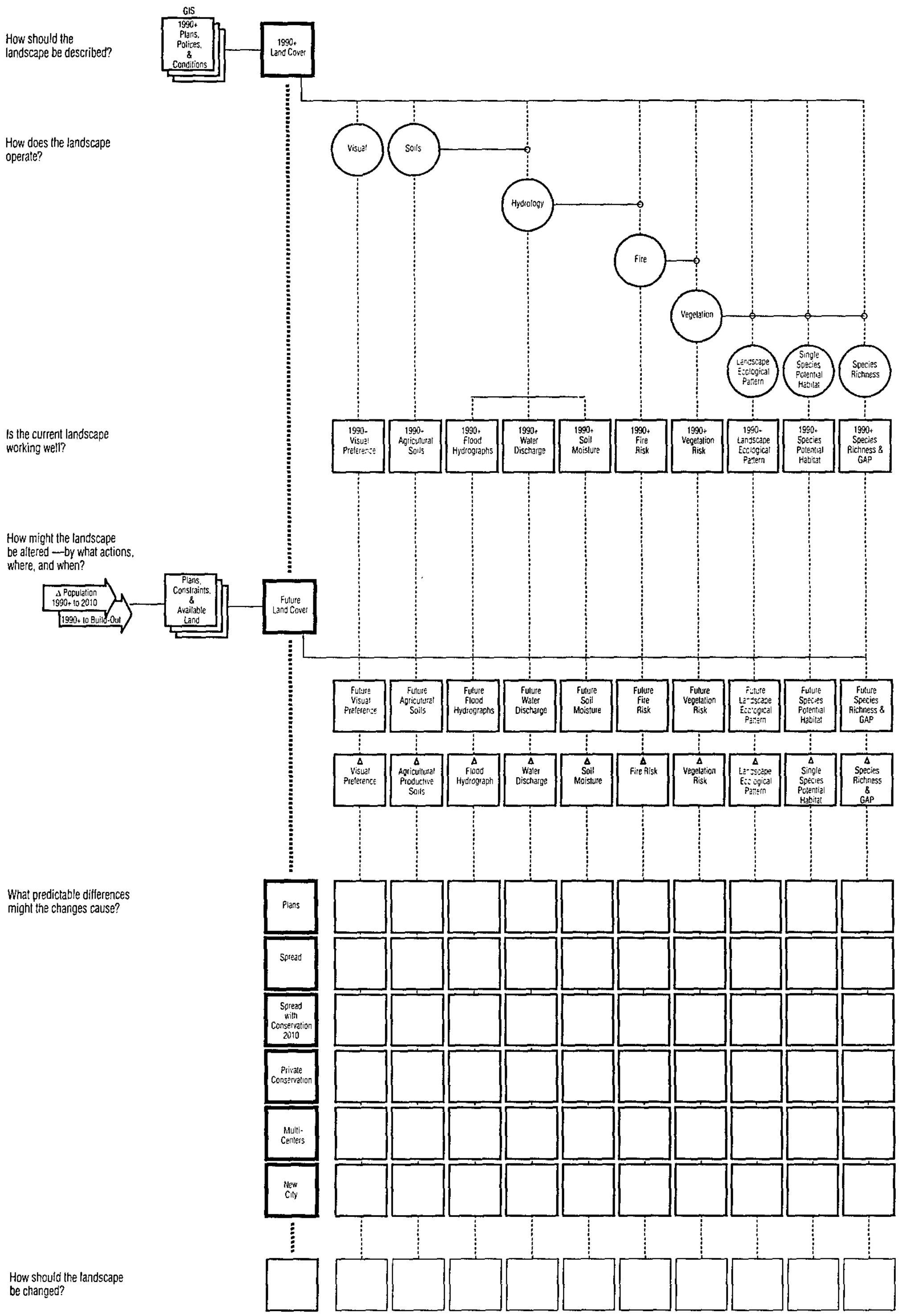
I. How should the state of the landscape be described: in content, space, and time?
In essence, this requires defining a vocabulary and a syntax to identify those characteristics of a place relevant to a particular study. To describe the static and dynamic processes at work in this very large study area, a computer-based Geographic Information System, or GIS, was organized to contain spatially explicit data on the region. The information available for this area included elevation, soil type, annual rainfall, vegetation, hydrology, roads, land-use, and public land ownership. With the GIS, it is possible to represent the state of the landscape with maps, charts, and diagrams that are derived from the data.

II. How does the landscape operate? What are the functional and structural relationships among its elements?
Once the pertinent components of the landscape have been identified and defined, relationships between the parts can be established. These processes can be cultural, such as land management and protection status or visual preference; or physical, such as flooding or soil moisture; or biological, such as potential California gnatcatcher habitat. In most cases, these relationships can be modeled using the available data in the GIS.

III. Is the current landscape working well?
The initial evaluation of the landscape is made by

Figure 5

Figure 6



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operating the process models on the data that represents the baseline state of the study. The baseline for this study is taken to be sometime between 1990 and the present, the period when the various data were generated. The existing conditions are noted in the text by **1990+**. The qualified "working well" question, of course, requires the establishment of measures of judgment. For this study, some evaluations included watershed flood hydrograph and water discharge, soil moisture, risk of fire and of fire suppression, and visual preference. Biodiversity was evaluated three different ways: by the landscape ecological pattern, by models that assess potential habitat for several amphibian, reptile, bird, and mammal species, and by total species abundance or richness, which is derived from vegetation communities. Although these three models of biodiversity are interrelated, each is based on a different premise and may present different implications for landscape planning and management.

IV. How might the landscape be altered –by what actions, where, and when?
At least two important types of change should be considered: those brought about by current trends and those caused by the implementation of purposeful change via actions such as plans, investments, and regulations. Future change for the region of Camp Pendleton is simulated via the complete implementation, or "build-out," of the area's current plans as summarized by the regional planning agencies, SCAG and SANDAG, and by MCB Camp Pendleton. In addition to this scenario, called **Plans Build-Out**, five alternative scenarios for the future urbanization of the study region reflect different development and conservation policies.

Alternative #1 illustrates the implications of the spread of extensive single family and rural residential growth with an assumed weakening or disregard of the regional plan, and with no additional conservation programs. Alternative #2 also follows spread development, but it introduces a major conservation effort in the year 2010. Alternative #3 proposes private conservation by encouraging large lot ownership adjacent to and within important habitat areas which are in turn protected by the homeowners as a means to conserve biodiversity. Alternative #4 employs a multi-centers approach by focusing on cluster development and new communities with extensive conservation efforts. Alternative #5 concentrates growth in a single new city. All of the alternatives accommodate the projected population forecast for the year 2010, and were then extended to build-out.

V. What predictable differences might the changes cause?
Operating the process models on the change scenarios and comparing the results with the baseline evaluations yields impact assessments. This investigation of the Camp Pendleton region is based on the premise that the major stressors affecting biodiversity are urbanization-related activities. There are direct impacts on habitat caused by deforestation, grading, paving, ornamental landscape planting, and other human activities that alter or destroy plant communities. There are also indirect effects of development, such as modified hydrologic cycles and fire suppression in rural areas. While the indirect effects can remain unnoticed by the casual observer, their cumulative modification to the landscape can be as detrimental to biodiversity as the direct impacts. For this reason the research team is reporting contributing impacts, such as change in soil moisture, that are beyond those immediately associated with biodiversity studies.

VI. How should the landscape be changed?
Each of the impact assessments reveals one aspect of how the alternative scenarios are predicted to change the landscape. The alternative scenarios for the region of Camp Pendleton, presented here, and their projected impacts may be used by stakeholders of southern California, including MCB Camp Pendleton, to assess the desirability of the various policies which generated them. The criteria by which choices are assessed will vary among individuals and groups who hold different interests. Judging the importance of these is the responsibility of the people and jurisdictions that will be influenced by future development.

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Some decision-oriented questions posed to the research team are:

From the perspectives of the BRC and the EPA:

What are alternative measures of biodiversity?

What types, magnitude, and time scale of environmental stress (e.g. flood, fire, development) cause what kinds of changes in biodiversity?

What are potentially effective strategies for the conservation of biodiversity?

Can a modeling approach to landscape planning be shared by area stakeholders, such as federal agencies, state and local governments, Indian nations, and private interests, as a basis for planning and negotiation?

What are the technical costs and benefits of a computer simulated modeling approach to landscape planning for biodiversity?

From the perspective of the DoD and SERDP:

Given that the Department of Defense is the third largest federal land holder, can appropriate management of biodiversity and landscape planning allow the military to more effectively manage its property and efficiently fulfill its mission?

From the perspective of the citizens, elected officials, and regional planning agencies of the region, and the EPA :

How might the existing plans and policies of the area affect the changing pattern of development? What are some environmental consequences?

What alternative scenarios for the future should be considered in the study region for the next 15 years? What are some of their comparative environmental costs and benefits?

And, from the perspective of MCB Camp Pendleton:

What are the roles of Camp Pendleton in the maintenance of biodiversity in the region?

How might issues of biodiversity affect or influence land management activities of the Camp?

How might future development or conservation "upstream" from Camp Pendleton influence hydrology, ecosystems, and biodiversity on the base and thus potentially influence its primary mission of training?

What effect will development or conservation off-base have on the Camp's efforts to manage its ecosystem?

To engage these various issues the research is organized at four geographic scales:

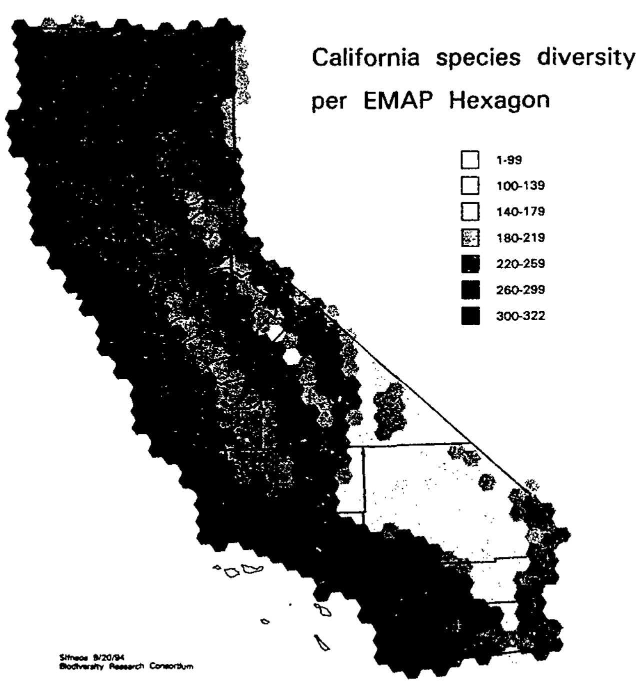
1) the region of Camp Pendleton is examined through several alternative planning scenarios; 2) "Oak Grove," a rural sub-watershed of the Santa Margarita River, is examined by comparing several different planning and development guidelines; 3) a residential subdivision on the biologically-sensitive Santa Rosa Plateau is examined via the creation of wildlife movement corridors within rural residential development; and 4) site-specific habitat improvements are proposed: a wildlife crossing for Interstate-15, and three zones of rare and endangered species habitat within Camp Pendleton which may be enhanced by landscape planning and design.

Given the need to assess biodiversity at a wide range of scales, from regional build-out to site specific habitat restoration, three models of biodiversity are incorporated in the research strategy: landscape ecological pattern, single species potential habitat models, and species richness.

Landscape Ecological Pattern

The landscape ecological pattern model builds from the ongoing work of Richard Forman and Michel Godron, as presented in their 1986 book, *Landscape Ecology*, and elaborated in Forman's 1995 book, *Land Mosaics*. The focus of landscape ecology is the spatial relationships between structural and functional elements of the land. Any type of landscape at any scale, whether natural or modified by human action, can be described as a mosaic: a background matrix and patches connected by corridors. This model provides a base for analysis and comparative evaluation, plus the potential for detecting general patterns and principles. Qualifications to the generalized elements can provide evaluations of the landscape. Change in the landscape ecological pattern of a region can cause a change in the biodiversity of the area, and planning initiatives that maintain the landscape pattern may preserve biodiversity.

Figure 7



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Single Species Potential Habitat

The single species potential habitat models map the possible home ranges for selected vertebrates based on food and nesting requirements, and on behavioral characteristics. While single species management has been criticized by wildlife biologists and planning professionals as being too narrowly focused, there are several reasons for integrating this type of modeling into a biodiversity study.

First, several species in the study area are on the federal lists of threatened and endangered species. The California gnatcatcher, least Bell's vireo, and arroyo toad are examples. Still other species are candidates for federal listing, or are listed as California Species of Special Concern. Consideration of those species is legally mandated. Some impact assessments, mitigation, or recovery management strategies clearly need to be species-specific.

Second, one species, the California cougar, is in danger of regional extinction because development and roadways are splitting the existing population into two increasingly isolated sub-populations. Without a habitat linkage, neither of these populations will be large enough to maintain genetic viability beyond the next 100 years. There are obvious species-specific planning, design, and management dimensions to this problem.

Third, some species are particularly susceptible to changes in the environment and, as such, are good indicators of environmental change associated with development. The least Bell's vireo, for example, is very sensitive to changes in hydrology, channel morphology, and riparian vegetation. In contrast, the brown-headed cowbird populations increase with suburban development.

The habitat information presented for each wildlife species has been formatted according to Standards for the Development of Habitat Suitability Index (HSI) Models of the U.S. Fish and Wildlife Service (1981). The HSI models are an outgrowth of the Habitat Evaluation Procedures (HEP)(USFWS, 1980). HEP is a widely used methodology for evaluating the various types of impacts on wildlife habitat and wildlife species associated with changes in water and land use.

Species Richness

Biologists have long used knowledge of species' life history attributes to model animal ecology. One common method is to model habitat by linking known needs and use patterns with maps of existing vegetation, thereby identifying the spatial extent of important habitat features. This information can then be used in conservation and management (see Verner, et al., 1986). For California, a complete set of wildlife habitat relation (WHR) models has been developed that links all terrestrial vertebrates to specific habitat types (Mayer, et al., 1988). By mapping the abundance, or richness, of species associated with each habitat type as derived from these relation models, it is possible to understand better the spatial implications of biodiversity in a region. The species richness approach does not focus on any particular species. Rather, it is an indicator of the properties of the set of all species associated with a pattern of vegetation.

The study region is currently an area of high biodiversity. Figure 7 shows the terrestrial vertebrate species richness of California. Each hexagon is 640km^2. The species richness values were made by assigning all individual species distribution maps to the hexagonal grid and then counting the number of species. Note the area of high species richness covering Camp Pendleton and its context region.

Technical Implementation

A computer-based Geographic Information System (GIS) was designed to contain digital data about the region, perform the analyses, and produce maps, charts, and other graphic and tabular results. A GIS is a type of database that allows descriptions of the landscape to be geographically referenced. Like many computer databases, a GIS can be searched for fact-based information, such as the amount of conservation land in the study area. Use of a GIS also permits analysis of the spatial relationships between elements in the landscape. For example, it is possible to query the *locations* of the conservation land in the study area. Further, models that use these spatially explict data can be created to simulate natural processes. Changes to the landscape can also be modeled and assessed for potential impacts.

The data used for this project were acquired from several sources and have variation in spatial resolution and accuracy. Sources ranged from detailed observations made by wildlife biologists in the field to descriptions of roads and stream networks from the national data bases of the United States Geological Survey (USGS) and the Census Bureau. Additional data were provided to the research team by SANDAG, SCAG, MCB Camp Pendleton, the University of California at Santa Barbara, and others. While most source data were acquired in digital form, some data, such as the county level soils surveys prepared by the Natural Resources Conservation Service (formerly the Soils Conservation Service), were digitized from printed originals. All data were assembled, standardized to a common set of descriptive terms, and combined to produce the study's representation of the landscape.

In the GIS for this project, separate digital "layers," or maps, are used to represent the important aspects of the study area: topography, soils, vegetation, hydrology, roads, existing and planned land use, county and municipal boundaries, etc. Each separate layer is stored in "raster" form, which is a two dimensional array of "grid-cells," or "pixels." Each individual pixel represents a 30 meter x 30 meter area (approximately nine-one hundreths of a hectare, or one-quarter of an acre). Thus, each data layer of the 80km x 134km study area is represented in the GIS as a matrix of approximately 4,000 cells east-west by 3,000 cells north-south, for a total of about 12 million cells. In addition, a number of linear features, such as roads, streams, county, municipal and other legal boundaries, are maintained as a linear or "vector" data base.

The analytical models that use the base data were implemented as computer program modules using the Arc/Info GRID analysis package (Environmental Systems Research Institute, Redlands, California). Additional data re-classification and satellite data interpration was performed in IMAGINE software (ERDAS, Atlanta, Georgia). Each model combines selected layers of the base data to analyze or predict some aspect of the structure or function of the regional landscape. Some models require as an input the results of other models. This "chaining" process can be seen, for example, in the cougar habitat model which is partly dependent upon mule deer habitat. The alternative future scenarios were developed in Map•Factory GIS software (Think Space, Ontario, Canada). Each scenario was represented as a land cover map with the same land use classifications as the **1990+** baseline, thus making it possible to compare present and possible future conditions.

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The results of most models are represented by one or more thematic maps. A thematic map might represent a conditional state, such as land cover in **1990+**, or an evaluation of species richness, or an impact such as loss of productive agricultural soil. Colors are used to identify different categories of that theme, or relative degrees of a characteristic such as density of development or soil moisture. In almost all cases, maps are rendered on shaded relief to clarify the relationships between the map theme, the physiographic terrain, and the hydrologic pattern of the study region, as shown in figure 8. Map legends show the area that is in a map catagory. "Change" bar charts show the gain or loss of a map catagory between any two time stage, typically 1990+ and Build-Out. The change bar charts separately display change on MCB Camp Pendleton (noted by %P) and in the watershed-defined study region (noted by %R).

This study has been conducted using metric measures in Standard International Units (SIU). For the benefit of readers unfamiliar with the metric system, the following approximate conversion factors may be useful:

1.0 foot (ft) ≈ 0.3 meters (m)
1.0 meter (m) ≈ 3.3 feet (ft)

1.0 mile (mi) ≈ 1.6 kilometers (km)
1.0 kilometer (km) ≈ 0.6 miles (mi)

1.0 acre (A) ≈ 0.4 hectares (ha)
1.0 hectare (ha) ≈ 2.5 acres (A)

°Fahrenheit = °Celsius x 1.8 + 32
e.g. 0° Celsius = 32° Fahrenheit

In this study:

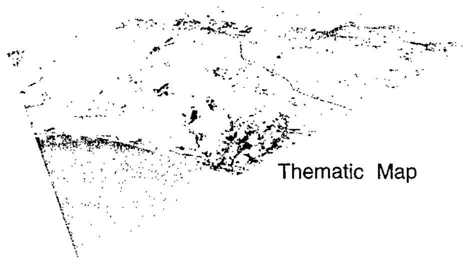
cell resolution = 30 meters ≈ 100 feet

one grid cell (30m x 30m) ≈ 0.25 acre

Total study area ≈ 1,000,000 hectares, or
≈ 2,500,000 acres

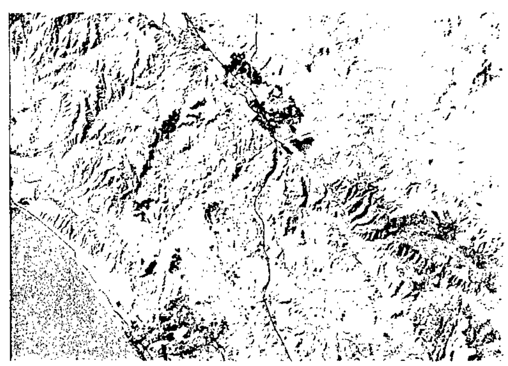
Total study area ≈ 10720 square kilometers or
≈ 4120 square miles

Figure 8

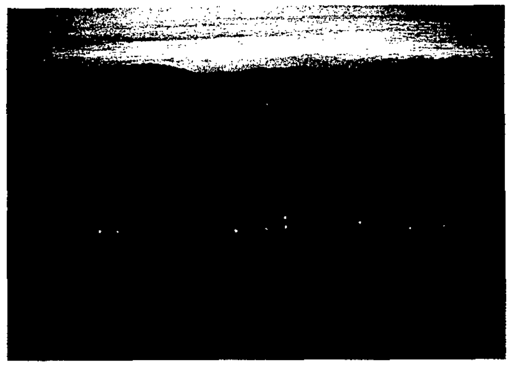


Thematic Map

Digital Terrain Model



Thematic Shaded Relief Map



The region of Camp Pendleton for this study has been defined as a 80km x 134km rectangle that encompasses the five major river drainage basins that directly influence Camp Pendleton. The watersheds of the San Juan, San Mateo, San Onofre, Santa Margarita, and San Luis Rey Rivers, are outlined on all maps. It is within these defined areas that changes associated with the alternative futures will be compared.

Figure 9 shows the physiographic provinces of the study area: the coastal plains, the foothills, the Temecula Valley, the mountains, and at the eastern edge, the desert.

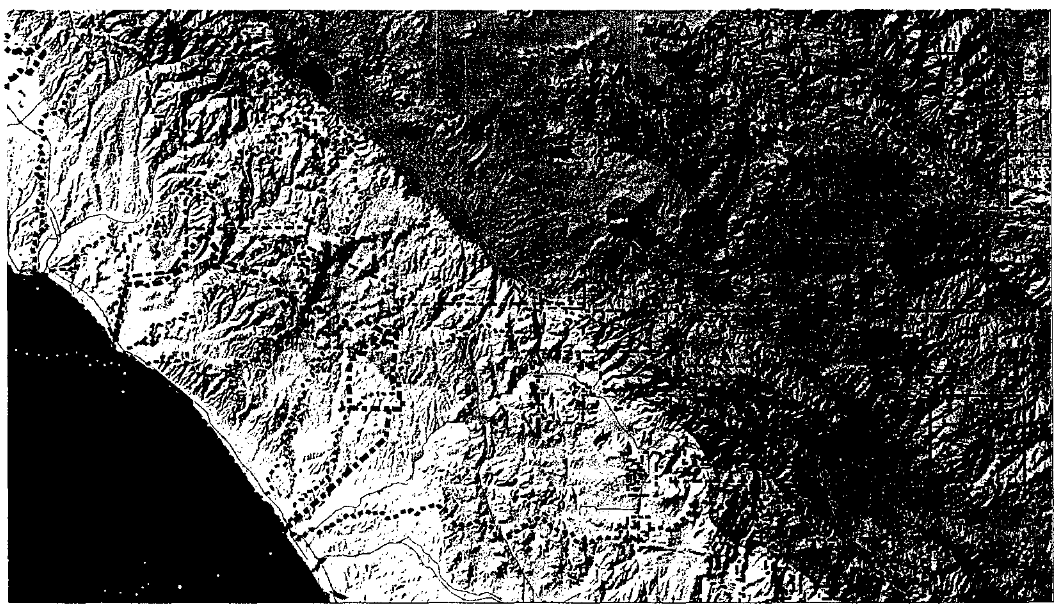


Figure 9

Physiographic Regions

Coastal Plains 441650 ha 12%

Foothills 808147 ha 23%

Temecula Valley 425599 ha 12%

Mountains 1180806 ha 33%

Desert 216301 ha 6%

0 1 3 5 kilometers

0 1 3 5 miles

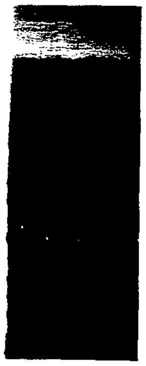


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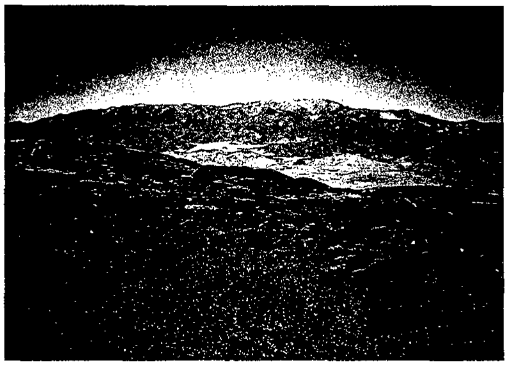
Figure
9

The coastal plains are rolling to steep topography with fairly smooth terraces that support a natural cover of chaparral and grassland. In the narrow winding valleys, oak is the dominant vegetation. There are also introduced eucalyptus and other exotic trees. The unequal altitudes of terraces of the same age indicate geologic uplift as the major cause in forming the terraces. The lowest terraces have been cut by waves and have distinct cliffs or escarpments along their seaward edge. The elevation of the marine terraces ranges from nearly sea level to about 250m.

The coastal plains have the most equable climate of any area in the country. As with most of the study region, temperature and precipitation vary directly according to elevation, distance from the coast, and solar aspect. Generally, the temperature decreases and the precipitation increases with rising elevation. The mean annual temperature of the coastal plains is 15° Celsius, with a mean minimum temperature in January of 6°C. The frost-free season is 280 - 360 days and the winter growing season experiences only light frost. Annual rainfall ranges from 0.3 - 0.4m, and 90% of this falls between November and April. Most soils are thoroughly moistened during this period, but little leaching occurs. Soil moisture is used up during rapid plant growth from early spring through June. Unless irrigated, the soils are dry by summer and soil moisture becomes the main factor limiting plant growth.

The foothills are a belt of narrow winding valleys and rolling uplands that have few very steep slopes. This zone lies between the coastal plains and the mountains. It is about 45km wide and extends in a northwest-southeast direction through Orange and Riverside Counties to the Mexican border. Chaparral, open woodland, and isolated areas of open grassland make up the typical plant cover. The elevation ranges from about 180m - 610m. The valleys are important farming areas, yet are subject to gully and sheet erosion.

The climate in the foothills is similar to that of the coastal plains; the mean annual temperature is 16°C., with a mean minimum temperature in January of 3°C. The frost-free season is 220 - 340 days, and again, the winter growing season has only light frost. Rainfall is heaviest from November to April and ranges varying from 0.3 - 0.5m per year depending on elevation and location. The parent material of the soils in this area and east to the mountains is decomposed granite, containing quartz fragments and other minerals. When carried by storm runoff, these materials act as an abrasive. The soils are generally classified as sandy loams and vary widely in depth. Organic matter is oxidized during the long, dry summer; thus, the soils are low in organic-carbon content.

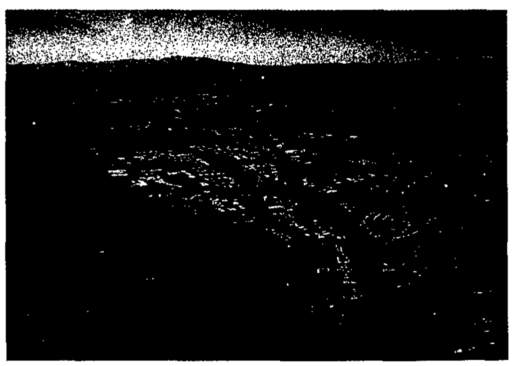


The topography of the mountain zone is rugged, with steep-walled bouldery peaks. The elevation ranges from approximately 600 to over 1800m. The mountain range has a northwest-southeast trend but is broken by faults and river valleys. The steep topography, the rockiness, and shallow depth of topsoils make the greater part of this area unusable for crop cultivation.

Vegetation is more abundant in the mountains than in other parts of the area and consists of various pines, Douglas fir, white fir, black oak, interior live oak, and incense-cedar. There are also areas of grassland and chaparral. The cool climate slows the rate at which micro-organisms reduce the supply of organic matter, so these soils have the highest organic-carbon content of any soils in the study area. Soils under the pine and oak trees have mats 2 -14cm thick of fresh and somewhat decomposed needles, leaves, and twigs. The mountain area is the wettest part of the area, receiving 30 - 100cm of precipitation, and the coolest, with an annual mean temperature of 13°C. The mean minimum temperature in January is 0°C and the frost-free season is 150 - 200 days.

At the edge of the study area and extending to the east is the desert, which includes areas of Borrego badlands, lacustrine deposits, and very rocky barren hills. It is an area of nearly level to moderately sloping alluvial fans and plains. Since the desert lies in the rain shadow of the mountains, it receives the least precipitation and has the least vegetation of any region in the survey area. Total annual rainfall ranges from less than 13cm - 25cm and for long periods there may be very little precipitation. Even when it does rain, however, there is not enough plant cover to control erosion. The desert has a wide range of seasonal and daily temperatures. The mean annual temperature is 22°C, and the mean minimum temperature in January is 2°C. The high temperature increases the rate of oxidation, so the organic-carbon content of the soils is very low. The frost-free season is 240 - 270 days. Soils in the desert area of the study tend to be saline-alkaline, because most of the moisture evaporates, leaving dissolved salts.

While not recognized as a physiographic province in the Natural Resource Conservation Service soils reports, the Temecula Valley, which includes the towns of Temecula, Elsinore, and Hemet, is perhaps the most significant physical subregion in the study area. Located north-east of MCB Camp Pendleton, this area is experiencing rapid urbanization. The terrain, climate, and soils combine to make the Temecula Valley relatively easy to convert to urban uses. The climate of the valley is Mediterranean, hot and dry in summer and cool and moist in winter. From May to October the rainfall averages 1.8cm at the lower elevations. Precipitation increases from September to November, peaks in December and January, and decreases rapidly in March and April. The soils in the area are typically well drained and deep, with a surface layer of sand or sandy loam. Vegetation is made up mostly of annual grassland, brushy chaparral, and sage. Some areas are devoted to orchard, vineyard, and other irrigated agricultural uses. Most of the valley is in the Santa Margarita River basin, which flows through Camp Pendleton. This is the subregion within which most of the future development associated with forecasted population growth is expected to occur.



Land Use and Population

The land use history of the study area is typical of development in southern California. During the middle 1760s Spain expanded its colonization in lower California, and in 1769 founded a mission in San Diego. The following year a second mission was established in Monterey. Thereafter the slow process of development began in California. The study region was at one time under the control of the missions of San Diego, San Juan Capistrano , and San Luis Rey (founded in 1769, 1775, and 1798 respectively). The extensive land holdings of the missions were important for sustenance and eventually supported grains, vineyards, olives, citrus, produce, and livestock.

A fall in the fortunes of the missions began in 1812, following an earthquake and the destruction of mission buildings. The decline reached its nadir during the period of 1826 to 1833 when, after the overthrow of Spanish rule, Mexican decrees ended control of the land by the missions. Most lands were distributed by grants to allies of the leaders in Mexico. Camp Pendleton is coincident with a part of the second largest land grant resulting from the division of San Luis Rey mission lands and which included much of the Santa Margarita watershed.

Records of the 1880s for the then State of California indicate that wildfires burned uncontrolled for weeks at a time. Lack of protection from fire caused serious damage to irrigation works and water supplies of San Diego and other growing coastal communities. The first State of California Forestry Commission, established in 1886 by Governor Stone, reflected the growing public concern for the land. A report by the commission demonstrated the need for watershed protection by stating that major fires and erosion were injuring the climate, agriculture, and future prospects of Southern California.

In 1893 President Benjamin Harrison set the cornerstone of the Cleveland National Forest by creating the 20,000ha Trabuco Canyon Forest Reserve in the Santa Ana Mountains. In 1897 President Grover Cleveland established the 280,000ha San Jacinto Reserve. In 1899 local petitions to the General Land Office were effective in more than doubling the size of the Trabuco Reserve. In 1908 President Theodore Roosevelt combined the Trabuco and San Jacinto Reserves into the 80,000ha Cleveland National Forest, named in honor of former President Grover Cleveland. Subsequent acquisition and the transfer of the remaining San Jacinto Unit to the San Bernardino National Forest established the Cleveland National Forest close to its present size of about 200,000ha.

From 1880 until World War II, the city of Los Angeles experienced a steady growth and industrial development. The construction of an artificial harbor at Long Beach and San Pedro some 40km from the center of Los Angeles secured for the city its role as a terminus of a transcontinental railway.

San Diego's growth during the same period was slow. The mild climate attracted large numbers of inmigrants, but it lacked the industry to support a growing population. In the 1920s an important Naval Base was located in San Diego and thus a basic economic factor was established which remains to this day. By the time World War II began, San Diego had also become the focus for a large aircraft industry.

The growth of agriculture as an industry, and an increasing population, were made possible only by the importation of water, a resource always near the verge of exhaustion in the region. The ambitious Owens Valley project, which brought water from the Sierra Nevada several hundred miles south to Los Angeles, enabled that area's population to grow. In the 1930s the Colorado River was tapped, and water was brought as far south as San Diego. These two massive water projects relieved southern California from dependence on limited and variable local ground and surface water supplies and encouraged the public's perception of limitless supply. Only recently has this perception changed.

The ever-increasing population of southern California since World War II has brought continuing suburban movement outward from the major cities, and as a consequence there has been a decrease and displacement of agricultural acreage. These pressures occurred most strongly along the coastal strip stretching from metropolitan Los Angeles to San Diego, relieved in part by the presence of Camp Pendleton.

Camp Pendleton was established in 1942 when the U.S. Government paid $4,000,000 for 49,867ha of what was formerly the Rancho Santa Margarita Las Flores. The large land area of the base still retains much of the landscape character of the early California days of missions and ranchos.

Camp Pendleton is ideally suited to meet the requirements of its training mission because of its location and terrain. However, the growing population of the surrounding communities and the growth of southern California in general may threaten Camp Pendleton's ability to conduct this training. The increasingly dense population surrounding the base has led to increased demands by the communities, and by government and private entities serving these communities, for the use of land currently a part of Camp Pendleton, such as the leased agricultural and recreational areas. It also places greater pressure for natural resource management on Camp Pendleton. At the same time there is an increasing interdependence between the base and the region in terms of off-base housing, economic relations, traffic, and the range of environmental issues that know no property or other jurisdictional boundaries.

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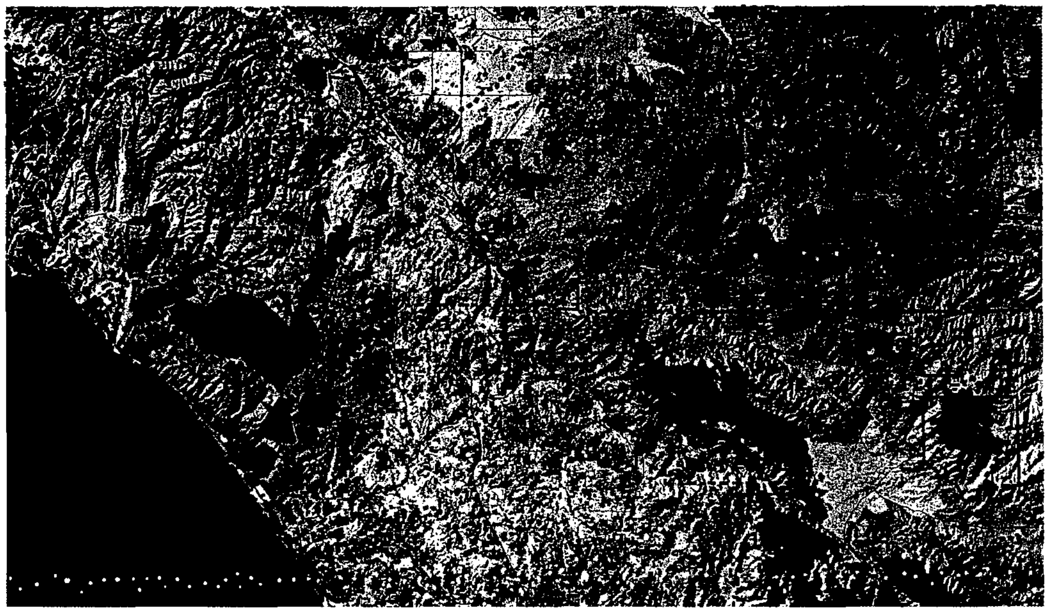
Figure 10



Land Cover: 1990+

Water	Mixed Forest	Grasslands	Single Family Res	Military Impact
	147617 ha 4% ha	168775 ha 5%	79521 ha 2%	50221 ha 1%
Riparian Vegetation	Orchards	Altered Land	Multi Family Residential	Commercial Industrial
21051 ha 1%	79808 ha 2%	161655 ha 5%	90344 ha 3%	86848 ha 2%
Oak Woodland	Sage. Chaparral	Rural Residential	Military Maneuvers	Trans- portation
131095 ha 4%	1640626 ha 46%	276226% 8%	117124 ha 3%	14105 ha 0%

0 1 3 5 kilometers
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Southern California, and particularly the area comprising the study region, has grown more rapidly since World War II than any region of like size in the United States. Increasing population brings increased land use and the prospect of the depletion of available land capable of development. The study area had an estimated combined population of 1.1 million in 1990. 'The Context Map,' figure 1, demonstrates that the study area and its communities are not isolated but rather are contiguous with the rest of the urbanized area within the Los Angeles-San Diego region.

For the purposes of describing the study region, the research team has adopted the convention of combining land use, vegetation, and terrain into a single map called 'Land Cover.' In this classification, urban land uses take precedence over vegetation for any given location. The classification of land cover is a generalization of the more than 200 groupings of vegetation and land use described by the local and regional plans in the study area. It is mapped in the following aggregate categories:

Water
Riparian Vegetation
Oak-woodland
Mixed Forest
Orchards
Sage, Chaparral
Grassland
"Altered Land," extensive agriculture
Rural Residential (1 house per 2ha)
Single Family Residential (1 house per 1/10ha)
Multi-family Residential (1 house per 1/20ha)
Military Maneuver
Military Impact
Commercial, Industrial
Transportation

Figure 10 shows the land cover for **1990+**.

Protection and Management

To assess the risks to biodiversity from potential development, there is the need to identify where such changes might occur. To that end, land in the study region was evaluated for its current degree of protection and management for biodiversity. The method for classification follows that used by the National Biological Service, in which the program of land use, and not ownership, is the principal rating factor. Similar classifications for the study area have been made by state and regional planning agencies. If land could be classified by two or more categories, the category representing more protection for biodiversity was mapped. The eleven categories used for this study are described below and are shown in figure 11.

1 Biological Reserves –the most protected
2 National Forests
3 Bureau of Land Management Lands
4 State, County, and Local Parks
5 Steep or Wet Land
6 Military Impact Areas
7 Military Maneuver Areas
8 Indian Reservations
9 Agricultural Land
10 Private Holdings
11 Urban Areas –the least protected

Of all of the types listed, only in Category 1, Biological Reserves, is the conservation of biodiversity defined as a primary management objective. Land on these sites is maintained in a natural state either by allowing natural disturbances, such as fire and flood, to occur or by simulating such events through management practices. Examples of Category 1 include the San Mateo National Wilderness and the Research Natural Areas of the

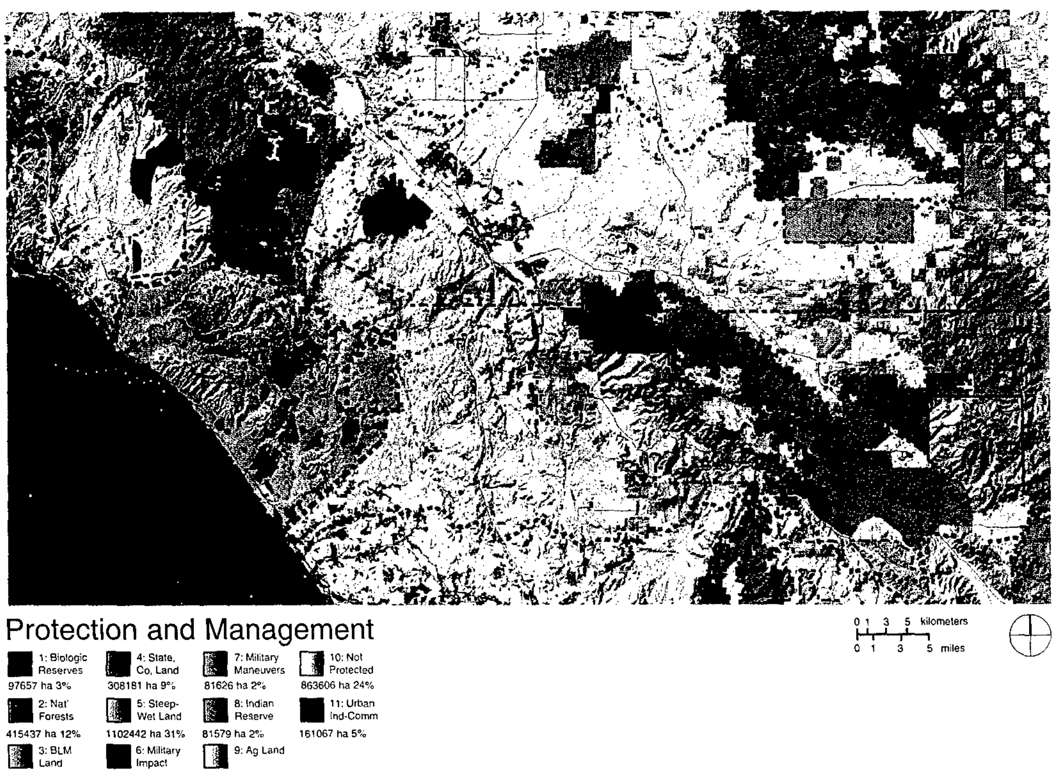

Figure 11

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Cleveland National Forest, Caspers Park, and the Santa Rosa Plateau Reserve, which is managed by The Nature Conservancy and other local agencies. Categories 2 through 4, which include lands administered by the National Forest, the Bureau of Land Management, and state and local government agencies, also contribute to the area's current high biodiversity, but do not conserve biodiversity as a predominant management or program objective.

Land in categories 5 through 11 can be developed given appropriate technologies and economies. Category 5, Steep or Wet Land, is difficult to develop, and may be protected by local building codes. Category 7, Military Maneuver Areas, could, in most cases, be converted to another use. Category 8, Indian Reservations, can be developed based on the decisions of the governing Native American tribes. Category 9, Agricultural Areas, and Category 10, Private Holdings, could be developed, and Category 11, Urban Lands, is already developed.

One category that requires a special note concerning the management of biodiversity is Category 6, Military Impact Areas. These are tracts that receive incoming ordnance from training exercises. As a result of this use, few people enter these areas and the threat of unexploded shells will make it difficult to develop this land in the future. Yet despite this, and perhaps because of the relative isolation from most human activities, many species are known to move through these areas and to use them for forage and nesting purposes. The frequent fires that accompany this land use also contribute to the quality of the grassland habitat, which requires burning for regeneration.

Figure 12, 'Constrained Land,' shows all developed land and all land assumed to be protected from urban development and Camp Pendleton's Impact Areas in their land cover colors. All other land, everything that can be developed at some point in the future, is shown as light gray shaded terrain.

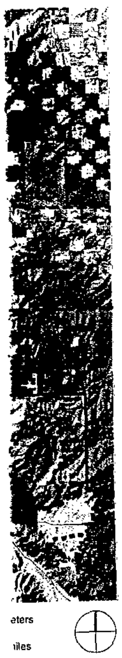
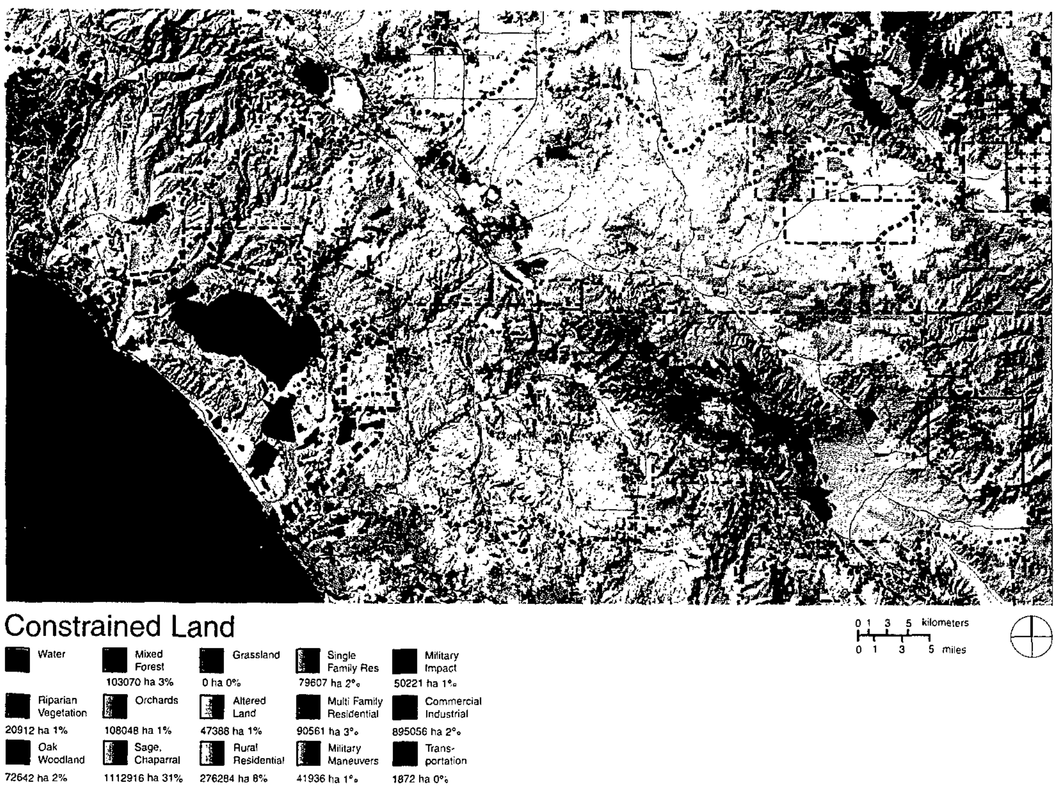


Figure 11

Figure 12



The plans of an area illustrate future intentions of land use including the anticipated needs for housing, recreation, transportation, commerce, and industry. They are generally prepared by or for governmental jurisdictions and are based on factors such as demographics, area economics, and environmental quality. The jurisdictions in the study area are shown in figure 13.

The summary of the region's plans for developable land is shown in figure 14. It was derived from generalized community land use plans, which are coordinated at the county and regional level by SANDAG and SCAG, from MCB Camp Pendleton, and from information on other federally owned lands and several large special projects. These were collated and reclassified into land cover categories. The sources include:

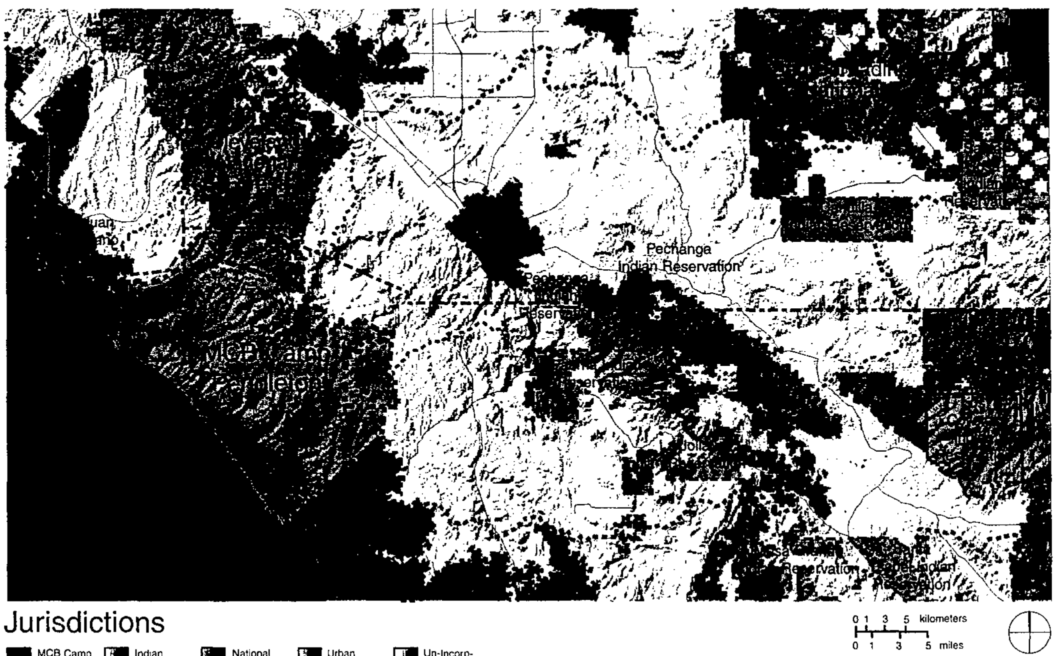
East Side Reservoir Project, "Plan," 1995.

MCB Camp Pendleton, "Draft: Possible Areas for New Facilities," 1995.

SANDAG, "Series 8 Planned Land Use," June 1994.

SCAG, "General Plans for Western Riverside County, Coachella Valley in Riverside County, and Orange County," January 1994.

U.S. Bureau of Land Management, "Public Lands." 1995.



Jurisdictions

Figure 13

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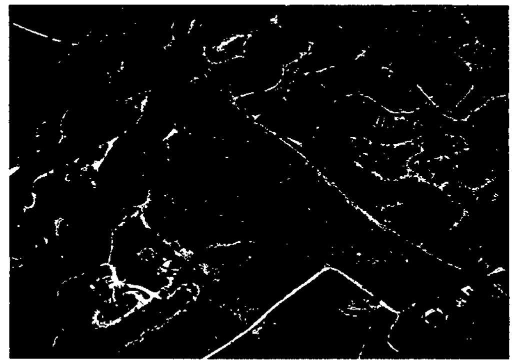


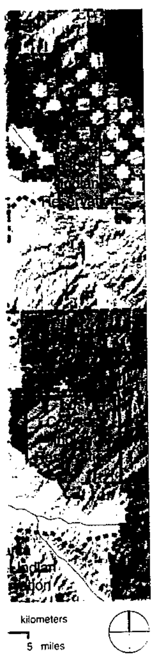
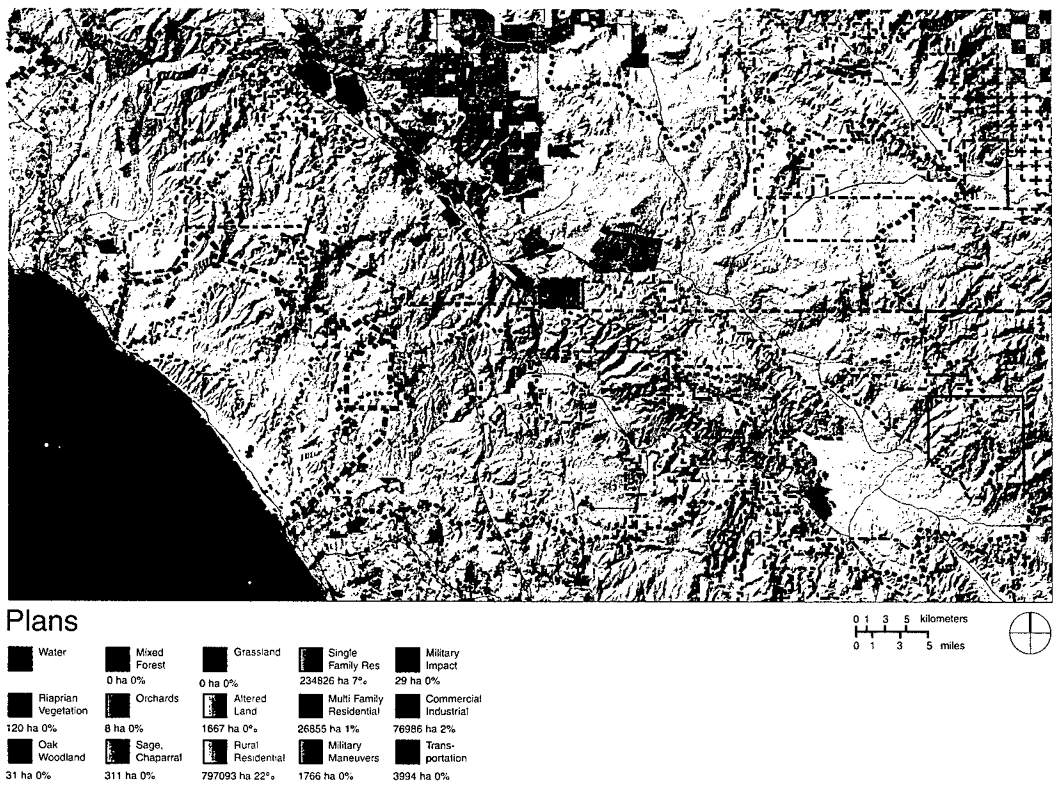


Figure 13

Figure 14



Plans Build-Out

The full implementation of the plans, or build-out, carries several assumptions, among them the continued demands of population growth, continued water supply, adherence to the plans, and the absence of compelling and intervening alternatives. Even though all of these assumptions can be questioned, the scenario based on local jurisdiction plans, called **Plans Build-Out**, is still the single most likely long-term future for the study area. It is this future scenario against which all other alternatives are compared.

In allocating change within the **Plans Build-Out** alternative, several constraints related to existing land use and land management policies were recognized and adopted. It was assumed that all existing "urban" land uses such as residential, commercial, industrial, and transportation would remain as they are, and that existing protection and management policies would be continued. In cases where the planned land use was less intensely developed than the **1990+** (existing) land use, the **1990+** category was maintained.

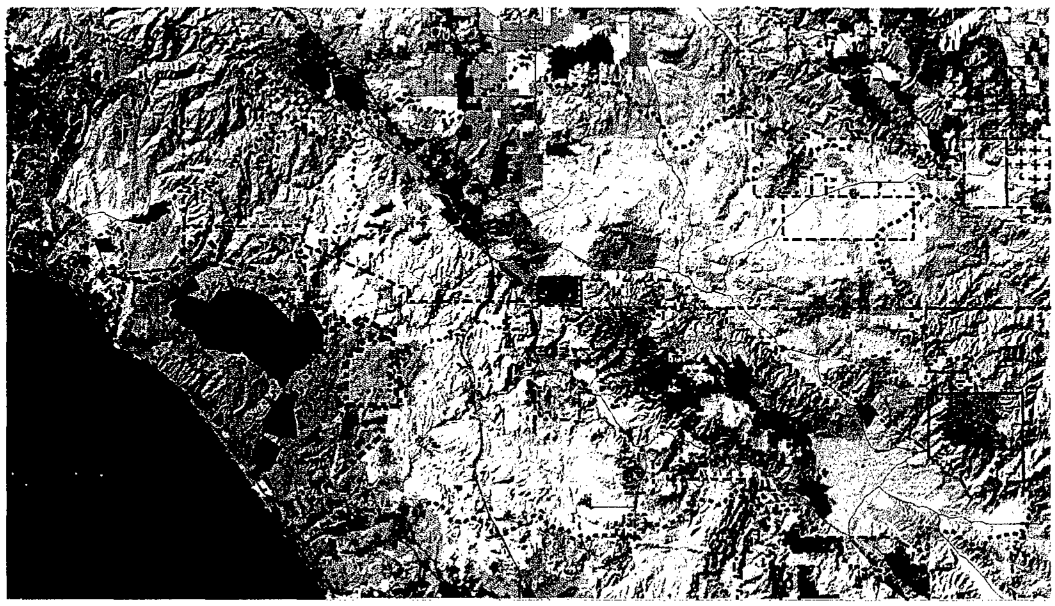


Figure 15

Land Cover: Plans Build-Out

Water	Mixed Forest 96610 ha 3%	Grassland 82780 ha 2%	Single Family Res 304038 ha 9%	Military Impact 49981 ha 1%
Riparian Vegetation 11453 ha 0%	Orchards 3887 ha 0%	Altered Land 67463 ha 2%	Multi Family Residential 110903 ha 3%	Commercial Industrial 155939 ha 4%
Oak Woodland 56713 ha 2%	Sage, Chaparral 1080648 ha 30%	Rural Residential 906378 ha 25%	Military Maneuvers 116374 ha 3%	Trans-portation 165638 ha 0%

0 1 3 5 kilometers
0 1 3 5 miles

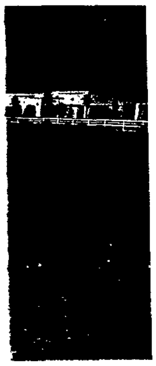


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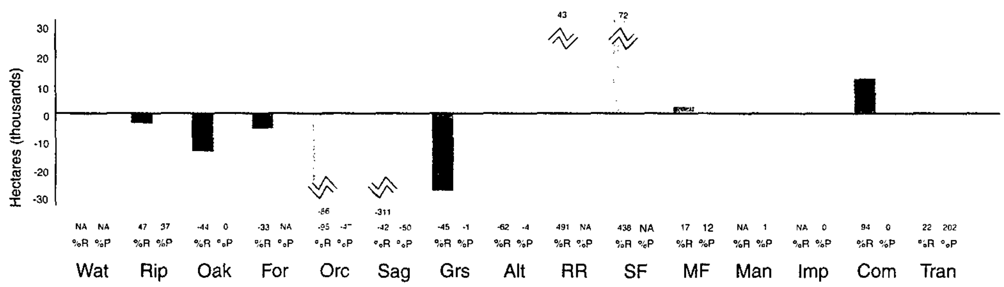
Figure
15

All lands in higher levels of protection, including bioreserves, National Forests, BLM lands, special districts, and state- and county-owned lands were considered un-developable. Military Impact areas were also considered un-developable. In the special case of Indian Reservations, which are not included in local and regional plans, it was assumed that they were developable at an overall rural residential density, while remaining subject to the full range of development and conservation alternatives. It was further assumed that land use allocation would be independent of property boundaries other than those already reflected in the plans and their zoning patterns. **Plans Build-Out** is based on the premise that if land is "unprotected" and developable, it will be altered (eventually) to its planned land use.

The changes in land cover between **1990+**, figure 11, and **Plans Build-Out**, figure 15, are summarized on the bar chart of figure 16. More than 500,000ha of natural land cover may be altered by conversion to residential uses. Most of the changes are caused by rural residential development and its fire protection zones, horse grazing, avocado plantations, and other non-native vegetation conversion.

NOTE: For the convenience of the reader, the inside back cover of this report is a fold-out that shows Land Cover **1990+** and Land Cover **Plans Build-Out**. In the analyses that follow, conditions in **1990+** and in **Plans Build-Out** are presented in a parallel format for comparison, as are changes from other alternative futures.

Figure
16

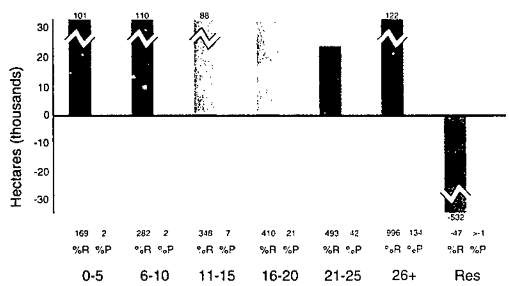


Land Cover: Change

Terrain

Several terrain characteristics will be influenced by change caused by **Plans Build-Out**. The slopes of the study region are shown in figure 17. The Plans and current development patterns indicate that the most intense urban changes will continue to occur on slopes of less than 5%. Furthermore, very little housing development to date has occurred on slopes of greater than 25%. Since this slope percentage is a policy constraint to development in several of the region's jurisdictions, it is likely to remain a constraining factor in the future. However, these slopes do allow for the planting of avocado orchards which place demands on the water system and provide minimal wildlife habitat value.

As shown in figure 18 and the bar chart in figure 19, there will be significant future development on slopes in the 5 - 15% range. In the cases of single family housing or more extensive commercial or industrial use, current economic forces, technical means and use-requirements are likely to combine to continue the major earth movement practices common in Orange, Riverside, and San Diego Counties. Much of the currently rolling terrain will be transformed into a more easily developable plateau-like landscape.



Developed Slopes: Change

Figure 19

Figure 19

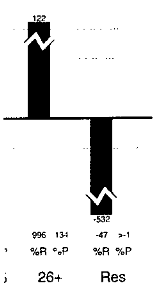
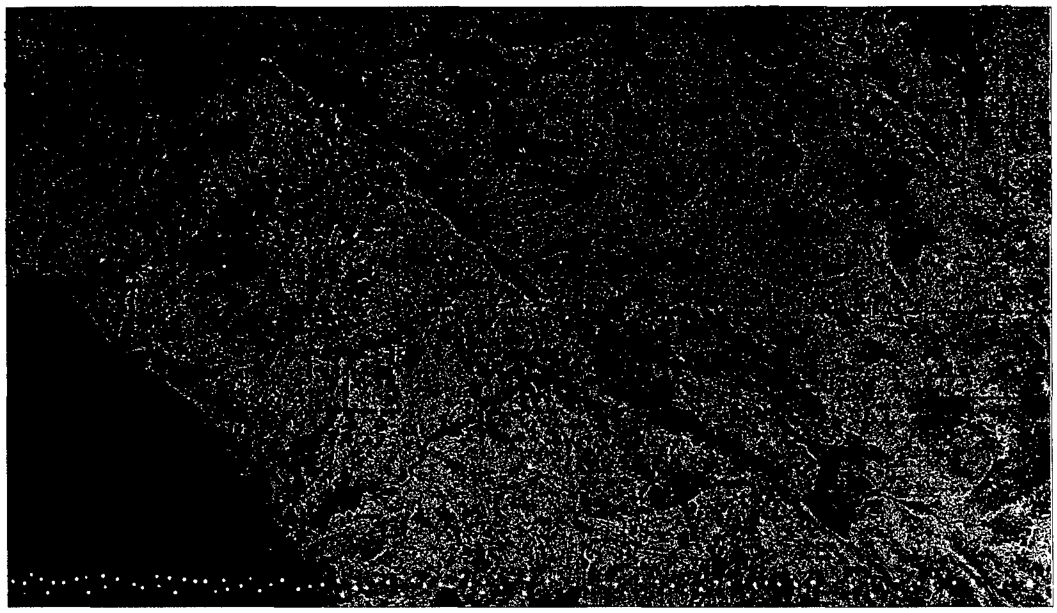


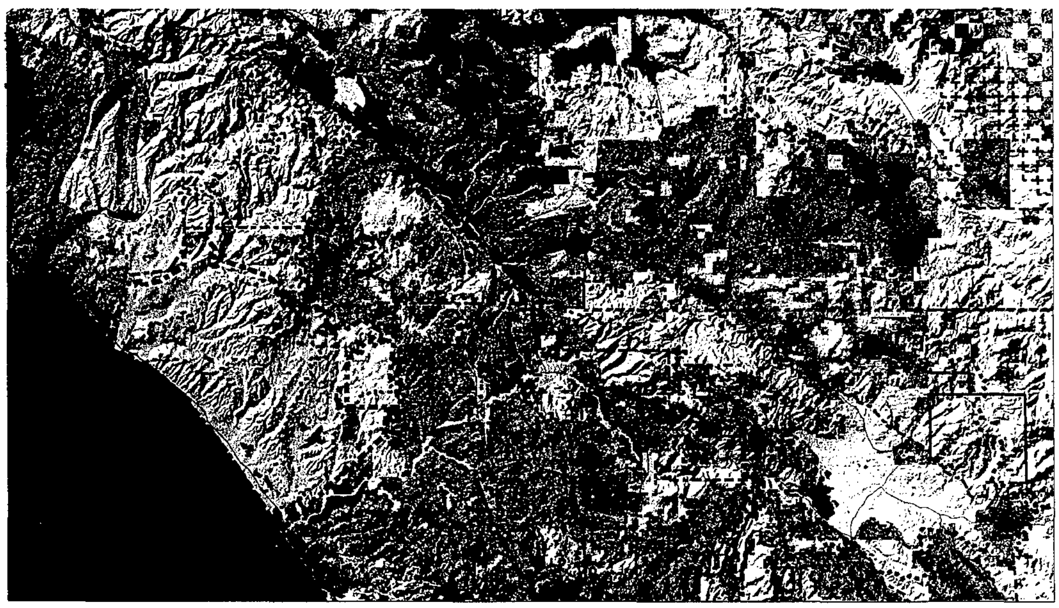
Figure 17



Slope in Percent Rise

0 to 5% — 1220803 ha 34%
6 to 10% — 451215 ha 13%
11 to 15% — 374796 ha 10%
16 to 20% — 305137 ha 9%
21 to 25% — 251961 ha 7%
26 +% — 970135 ha 27%

Figure 18



Built Slopes: Plans Build-Out

0 to 5% — 519320 ha 15%
6 to 10% — 277316 ha 8%
11 to 15% — 1999595 ha 6%
16 to 20% — 140862 ha 4%
21 to 25% — 101012 ha 3%
26 +% — 255731 ha 7%
Residual — 2080210 ha 58%

The soils of the study area vary widely in appearance, composition, management requirements, and productivity, even within short distances. The spatial distribution of soil types is shown in figure 20. Their characteristics are taken from the Natural Resources Conservation Service (NRCS) soil surveys for Orange, Riverside, and San Diego Counties. Coastal plains soils are typically well-drained sandy loams with a component of sandy clay which contributes to a relatively high fertility. Soils in this area are generally used for citrus, truck crops, avocados, and flowers.

Foothills soils are very to moderately well-drained sandy loams to silt loams that have a coarse sandy loam to clay subsoil. Soils in this region are used for citrus, avocados, and irrigated field crops. Mountain soils are excessively drained to well-drained loamy coarse sands to loams. In most areas, rock outcrops and large boulders are distributed widely. Soils in this area are generally unusable for crop cultivation and are suitable only for range and wildlife habitat. The hillsides have extremely shallow depth to granitic hardpan which presents serious problems for the introduction of either septic or public sewer systems.

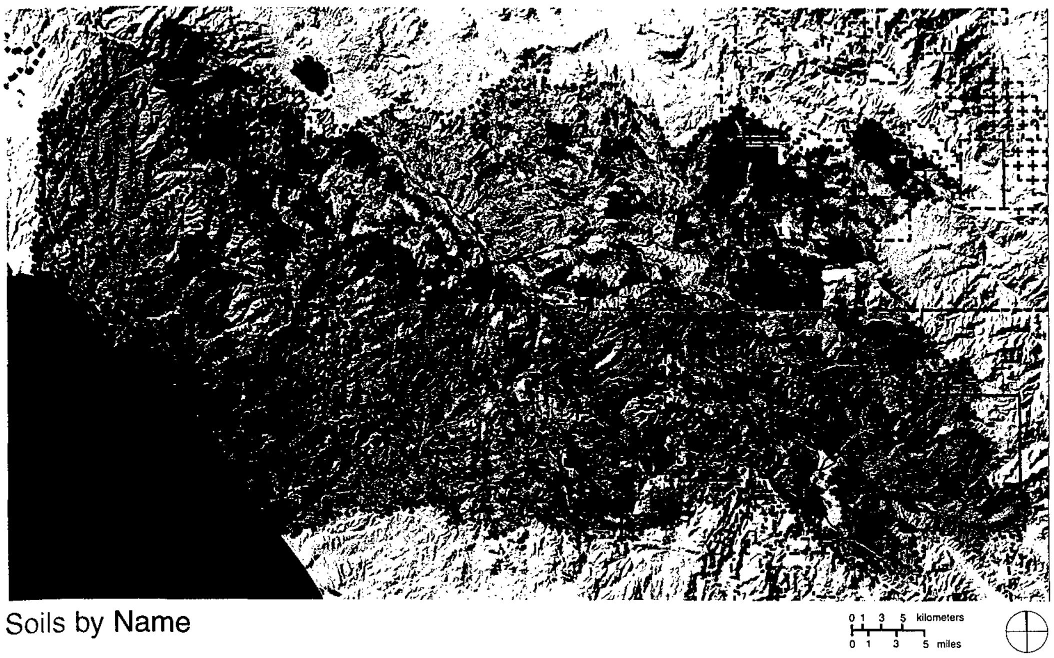


Figure 20

Soils by Name

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Figure 21 shows the region's soils when aggregated into their hydrologic soil groups. These are used for assessing soil erosion and surface water runoff.

Group A Soils have a high infiltration rate when thoroughly wetted. They are chiefly deep, well drained to excessively drained sand, gravel, or both.

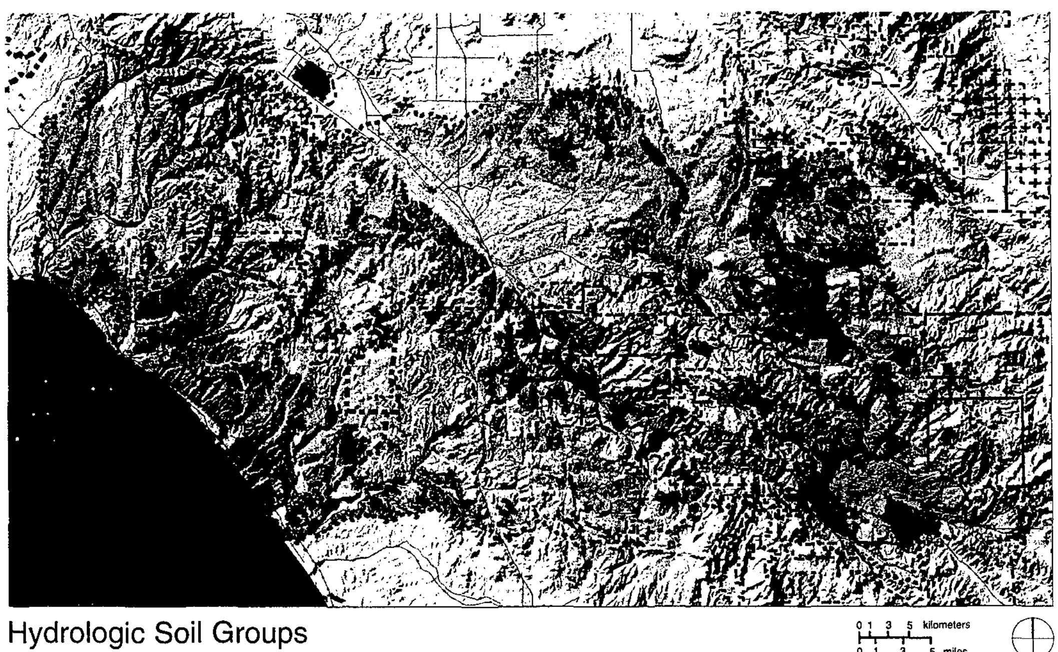
Group B Soils have a moderate infiltration rate. They are chiefly soils that are moderately deep to deep, moderately well drained to well drained, and moderately coarse textured.

Group C Soils have a slow infiltration rate. They are chiefly soils that have a layer impeding downward movement of water, or moderately fine to fine textured soils.

Group D Soils have a very slow infiltration rate. They are chiefly clays, soils that have a high permanent water table or a clay layer at or near the surface or shallow soils over nearly impervious material.

Figure 20

Figure 21



Hydrologic Soil Groups

Water

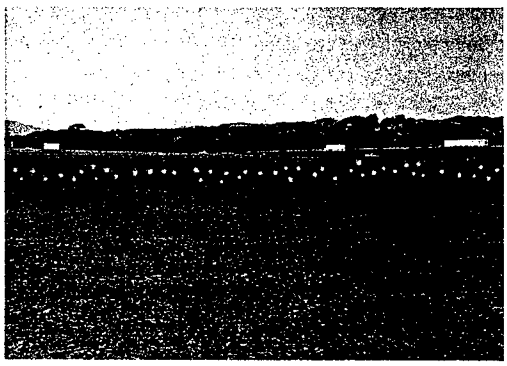
Group A
113840 ha 3%

Group B
358221 ha 10%

Group C
552627 ha 15%

Group D
449980 ha 13%

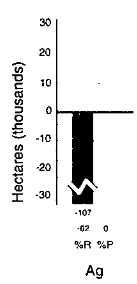
There are two major impacts on soil productivity associated with **Plans Build-out**. First, and most important, is the direct impact of the conversion of land with soils that are potentially productive for agriculture into single family development and other urban land uses. Figure 22 shows unbuilt areas listed by either the state of California or the NRCS as having prime or significant agricultural soils. Figure 23 shows the loss of these areas to development as a result of **Plans Build-Out**. About 100,000ha may be directly affected, as shown in the bar chart in figure 24.



Some of the potentially fertile land which is being developed may remain in agricultural use as part of a highly fragmented pattern associated with rural residential development. The current areas leased by Camp Pendleton for agricultural use will remain in **Plans Build-Out** and become increasingly valuable within the region as other productive soils are lost to development. Yet the location of these lands, in some of the most accessible and buildable parts of the base, may, in the long-term, threaten their continued agricultural use.

Plans Build-Out will also result in some indirect impacts. There is a widely seen relationship between rural housing and the creation of avocado orchards. Presuming the continuation of current patterns of land use, another consequence of the **Plans Build-Out** may be an increase in avocado planting. This would alter the vegetation pattern, negatively influencing several of the measures of biodiversity.

Figure 24



Prime Agricultural Soils: Change

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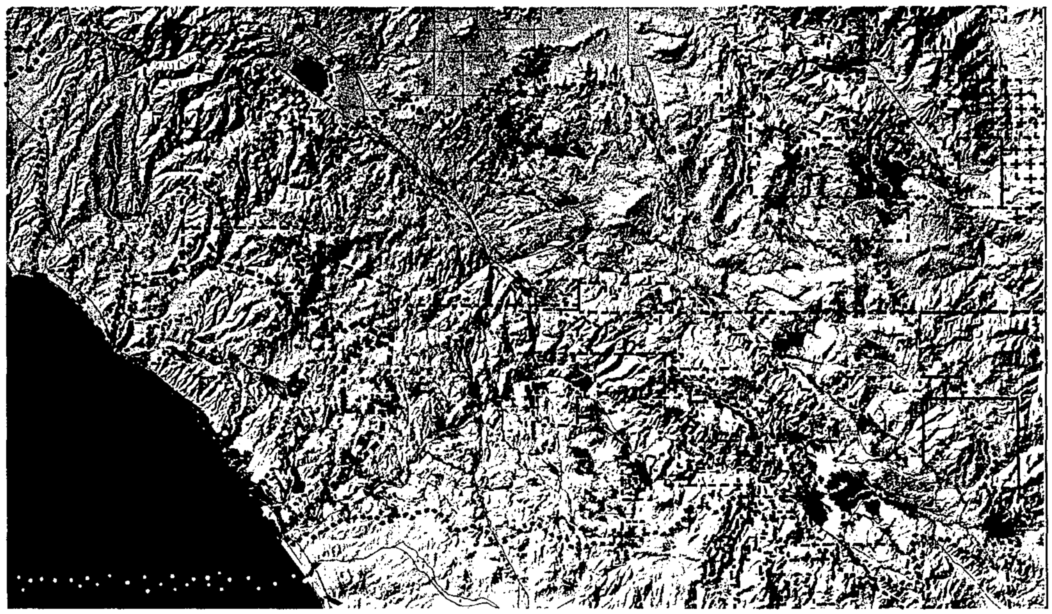
Figure 22

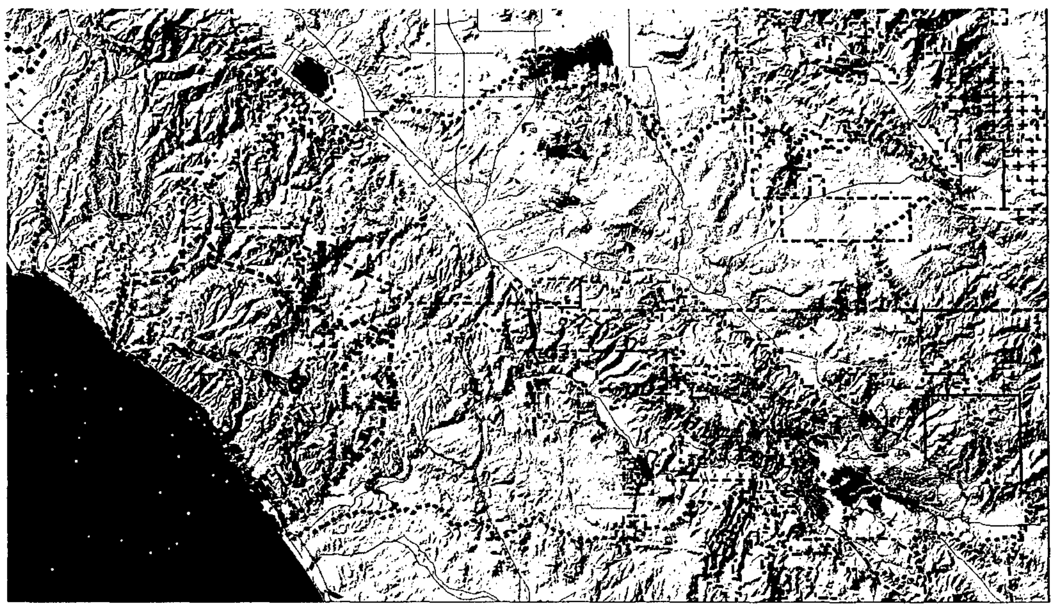


Prime Agricultural Soils: 1990+

Prime Ag Soils
201144 ha 6%

0 1 3 5 kilometers
0 1 3 5 miles

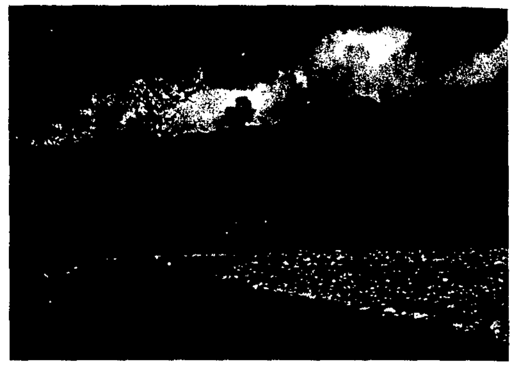
Figure 23



Prime Agricultural Soils: Plans Build-Out

Prime Ag Soils
94356 ha 3%

0 1 3 5 kilometers
0 1 3 5 miles



The hydrologic component of the study simulates the relationships between land cover and the hydrological regime. The models test different future alternatives and predict the indirect hydrological influences on vegetation, and thus on biodiversity. The estimation of flood flows, and consequent changes in flooding on Camp Pendleton, are intermediate products of the analysis.

Despite the popular image of "sunny southern California," the study region is a land of severe floods, the intensity and frequency of which will probably increase in response to upstream development. When land is converted from natural vegetation to built structures, the area of impervious ground cover and the velocity at which water runs off the land usually increase. Infiltration of precipitation into the soil decreases, causing more runoff and flooding during storms and less long-term recharge of soil moisture and aquifers. This process generates changes in hydrological regime in the associated terrestrial and downstream riparian and aquatic systems. Furthermore, floods of greater magnitude erode more sediment in areas of highly erodable soils –which are prevalent in this region– and also deposit more sediment downstream, thus changing riparian conditions.

Hydrological regime (i.e., the quantity, timing, location, and quality of available surface water, soil water, and groundwater) is one of the major factors controlling biodiversity in southern California. Hydrological regime is defined in terms of both single events and long-term patterns. The single-event perspective describes the flood that results from a rainstorm of some intensity, duration, and frequency that falls in a drainage basin with moisture already in the soils. The water that does not infiltrate the soil or evaporate into the atmosphere flows to and through the stream channel. If the volume of water exceeds the capacity of the channel to carry it, a flood results. Upstream land-use changes that lead to increased impervious areas usually increase peak discharge (discharge is the volume of water that flows past a point in the stream) and always increase total storm discharge.

The long-term perspective encompasses the precipitation from many storms, accounts for water losses from a basin via evapotranspiration and deep seepage, and examines daily or monthly fluctuations of soil moisture and streamflow, possibly for many years. This perspective allows estimates of water budgets for upland soils, as well as hydroperiods (length of time of standing water or saturated soil conditions) in riparian and floodplain areas. Procedures for simulating both long-term hydrological and single-event regimes are shown in the diagram in figure 25.

The relationship between hydrologic regime and vegetation, and thus biodiversity, can be interpreted and predicted as a consequence of either soil water availability or hydroperiod. Water availability controls edaphic factors for plant communities, which in turn provide habitat for animals. Thus, alterations to the hydrological regime will necessarily affect biodiversity, often in places distant from the source of the change.

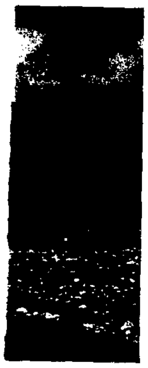


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Figure 25

Soil Moisture and Upland Vegetation

Flooding and Riparian Vegetation

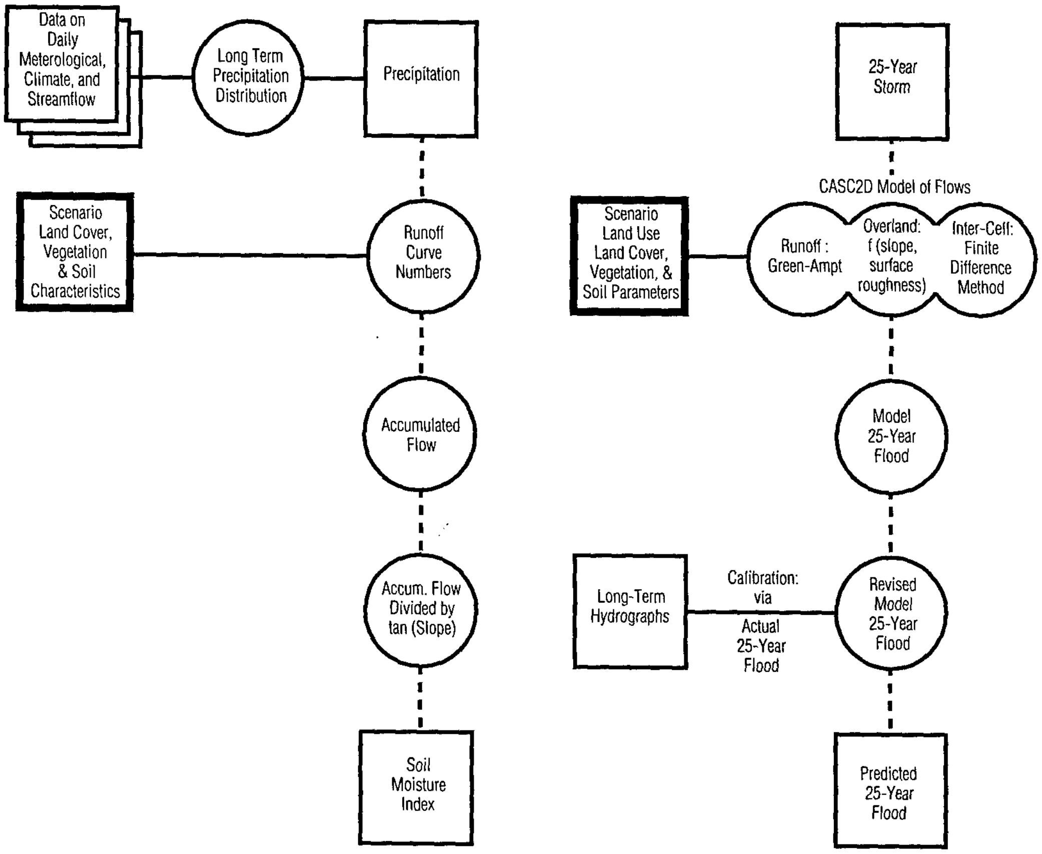
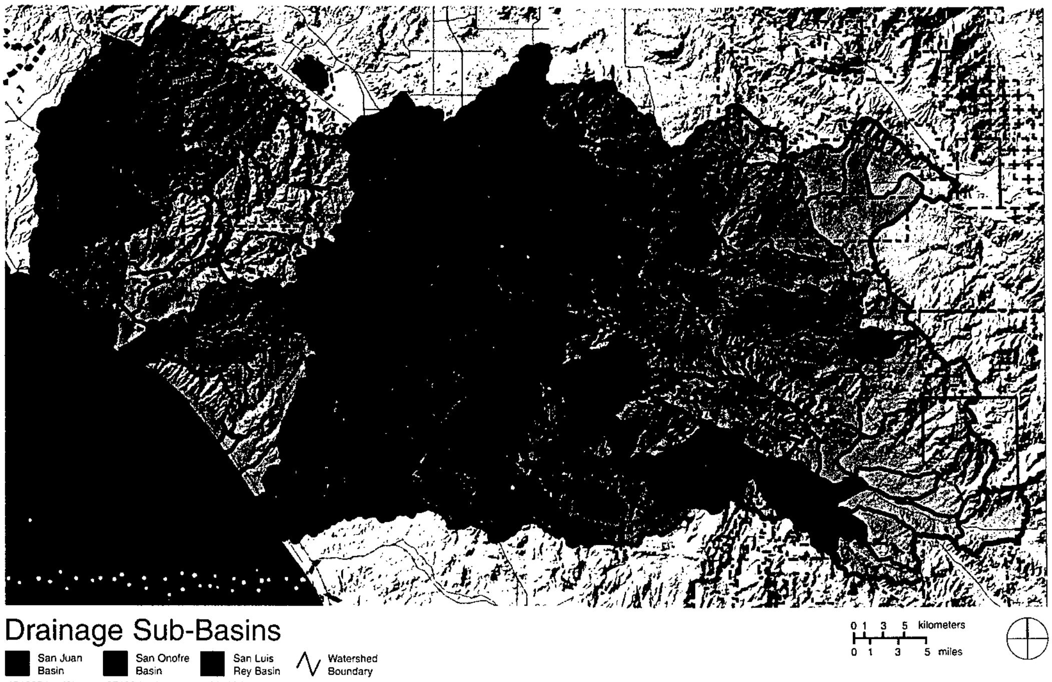


Figure 26



Drainage Sub-Basins

Figure 26 shows the seven drainage basins, or watersheds, that flow through or are adjacent to Camp Pendleton and empty into the Pacific Ocean. For purposes of analysis, these basins have been further subdivided into 113 third-order stream basins which are approximately the same size of towns and larger developments. The basins in this study are, from north to south, the San Juan River, several small creeks combined into the North Coastal Drainages, the San Mateo River, San Onofre Creek, the south coastal drainages including Las Pulgas Creek, the Santa Margarita River, and the San Luis Rey River. Headwaters for the main watersheds of the Camp Pendleton region originate on the western slopes of the Peninsular Range. The Santa Margarita River, the largest stream basin in the study area, flows southwest to the Pacific Ocean. Below the confluence of Murrieta and Temecula Creeks, the Santa Margarita is also southern California's only "free-flowing" river; it has no major dams.

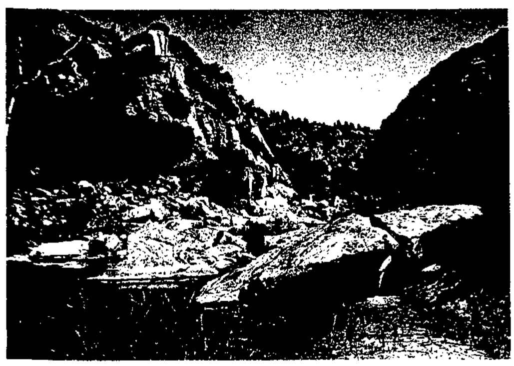
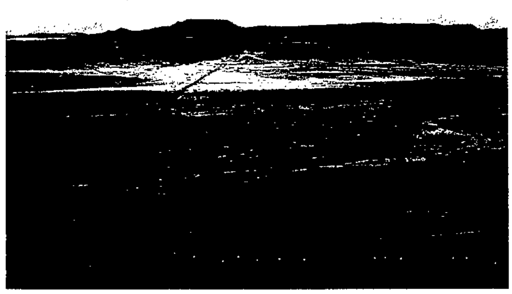


Figure 26

In some cases, such as the south coastal drainages and San Onofre Creek, the basins are completely enclosed by Camp Pendleton. In other cases, especially the Santa Margarita and San Mateo Rivers, most of the basin is upstream of the base and is under intense pressure for development.

Four important estuaries are on the base at the mouths of the Santa Margarita, San Onofre, Las Flores, and San Mateo Rivers, and minor estuaries exist at the mouths of all the coastal drainages. Two bordering river basins interact with Camp Pendleton in less significant ways, either by receiving treated sewage effluent (San Luis Rey River) or by encroaching slightly into Camp Pendleton property (San Juan River).

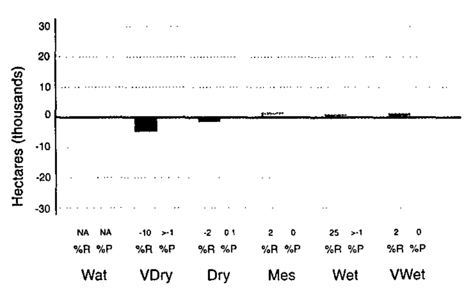
The lower portions of the Santa Margarita and San Onofre watersheds are characterized by alluvial valleys containing the principal source of water for Camp Pendleton. Camp Pendleton's domestic, agricultural, and industrial water supply is totally dependent on pumping from underground aquifers located on the base, which are recharged by percolation from rivers and streams. At present, Camp Pendleton has no direct connection to imported water, unlike most other places in southern California.



Long-term soil moisture budget and streamflow modeling define the relationships between vegetation types and soil-water budget and riparian hydroperiod, respectively. A soil-moisture index, defined as the total volume of water that flows through a 30m by 30m GIS grid cell during a year, divided by the tangent of the slope, is calculated (modified from O'Loughlin, 1986, Barling, et al., 1994).

Figure 27 shows the soil moisture index in the **1990+** base year; figure 28 shows the soil moisture index resulting from **Plans Build-Out**; and the bar chart in figure 29 shows their differences. Although more water runs off the upland areas that are developed, the entire study region, in general, becomes slightly wetter after **Plans Build-Out**, because water runs through the lowlands in greater volume. Thus, the upland soils become slightly drier but the lowland and riparian soils become much wetter.

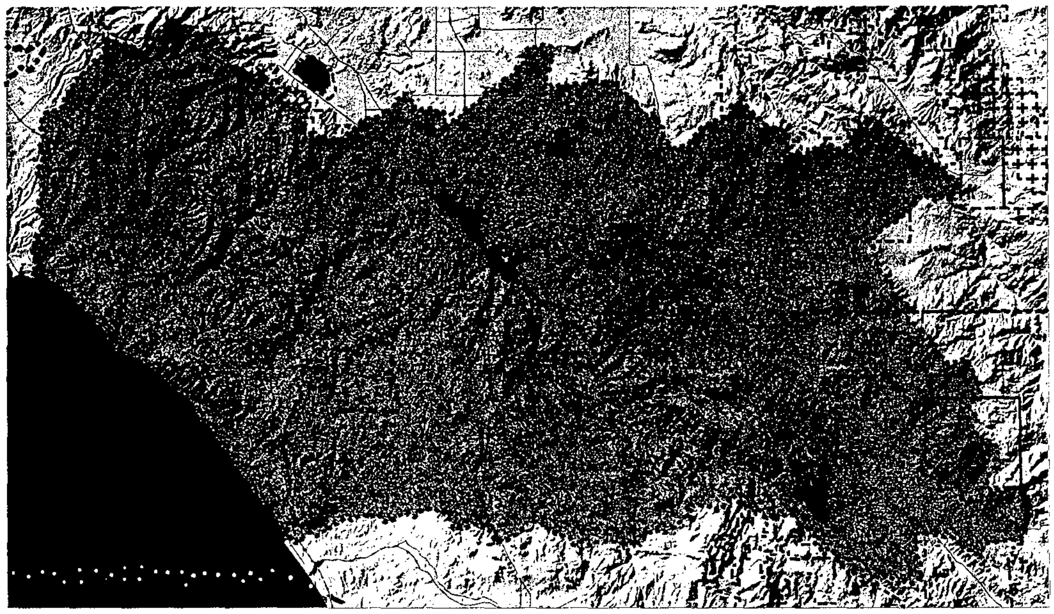
The consequences of this pattern of soil-moisture change on vegetation are subtle, but they indicate potential risk to the maintenance of current vegetation patterns, and thus biodiversity. In general, drier upland vegetation that is not converted to urban uses in **Plans Build-Out** will slowly grow into oak woodlands (see Callaway and Davis 1993 for evidence that this actually happens when fires are suppressed). Increases in downstream and lowland soil moisture and flooding could mean increases in the extent of exotic riparian vegetation, especially invasion by *Arundo donax*, as greater floods decimate existing riparian areas, leaving bare sediment available for colonization by opportunistic plant species.



Soil Moisture: Change

Figure 29

Figure 27



Soil Moisture: 1990+

Water

Mesic 237811 ha 8%

Very Dry 114053 ha 4%

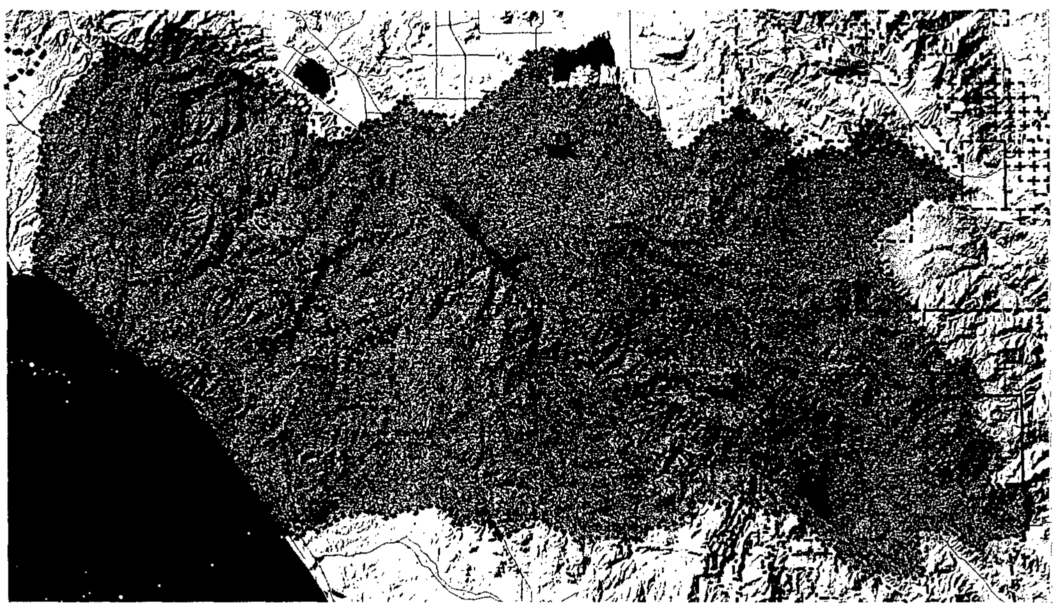
Wet 98413 ha 3%

Dry 237831 ha 8%

Very Wet 195646 ha 6%

0 1 3 5 kilometers
0 1 3 5 miles

Figure 28



Soil Moisture: Plans Build-Out

Water

Mesic 241516 ha 8%

Very Dry 104374 ha 3%

Wet 100577 ha 3%

Dry 234728 ha 7%

Very Wet 198550 ha 6%

0 1 3 5 kilometers
0 1 3 5 miles

Figure 29

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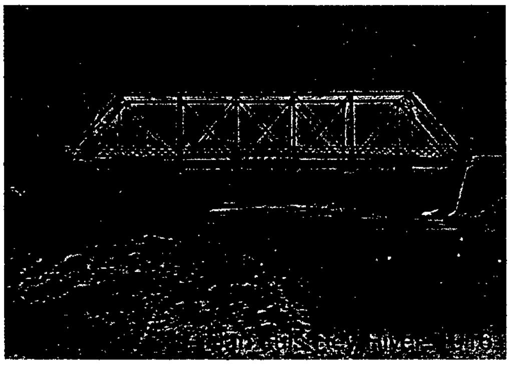
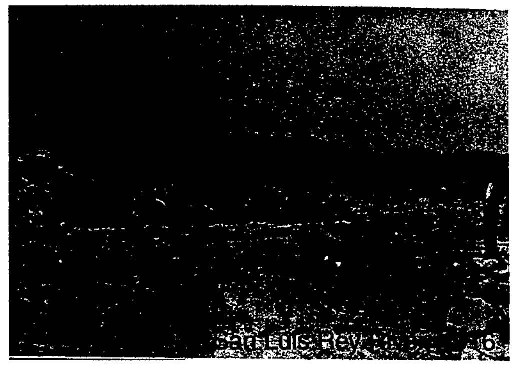


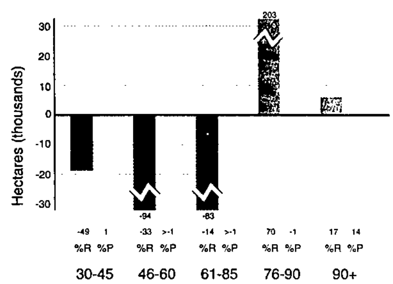


The potential for large floods is particularly high in this southern California region because of the extreme variability of precipitation and runoff. For example, successive soil-saturating storms in early 1993, combined with intense rainfall (175mm in 24 hours) in the upper watershed, led to record flooding in the Santa Margarita River Basin on January 16, 1993. At the damaged gaging station at Ysidora, the estimated peak discharge may have been greater than 1870m^3/sec, the highest for the 68 years of record. The 100-year peak flow at this gauging station is estimated (for flood control purposes) to be 2830m^3/sec and assumes that upstream storage sites are full, with a total five-day flood volume predicted to be 178,000,000m^3. This flood-control assumption does not consider the effects of expanded urbanization in the upper watershed, which is likely to cause large floods to become more frequent, and the largest floods to become even larger.

During the summer months in this Mediterranean climate, the frequency of extremely low flows in unregulated streams is particularly high. It is common for the San Mateo, San Onofre, and Los Flores Creeks to be dry from July through October. The Santa Margarita River has had no flow reaching the Pacific during about 26% of the period of record. Most of the tributaries to these rivers are also intermittent.

Floods produced by single-storm events are simulated by two methods, depending on the size of the basin. The first method, which is used for the third-order basins and is not spatially explicit, was originally developed by the U.S. Soil Conservation Service, now named the NRCS. This method uses the NRCS designation of hydrological soil group (HSG) for each named soil series to assign a Runoff Curve Number (RCN) to areas with characteristic combinations of soil and land cover. RCN is a variable used to calculate infiltration and runoff volumes from a given rainfall amount. Figure 30 is a map of RCN generated for the **1990+** land cover. Figure 31 shows the RCN in **Plans Build-out**. The models then calculate the total volume of runoff produced by a storm of a given intensity, and the runoff volume is then routed overland and through channels according to overland and channel flow models. Storm hydrographs (plots of discharge vs. time) are then calculated by summing the volume of water reaching a point of interest from all uphill sources.

The second analysis method is based on the Green-Ampt model of infiltration (Rawls, et al., 1983). Unlike the RCN approach, this model is spatially explicit and can simulate the effects of the location of future urban development. Because of this, it is more appropriate for larger basins. Rain falls on the landscape and, if not intercepted by vegetation or structures, either infiltrates or runs off. The factors that control these steps include rainfall intensity, the



Runoff Curve Number: Change

Figure 32

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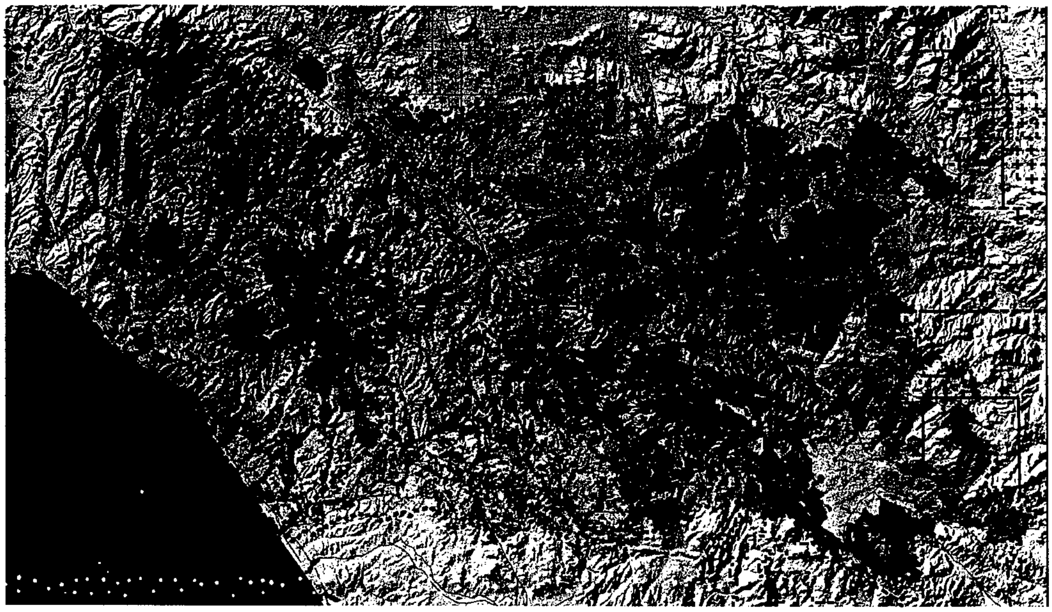
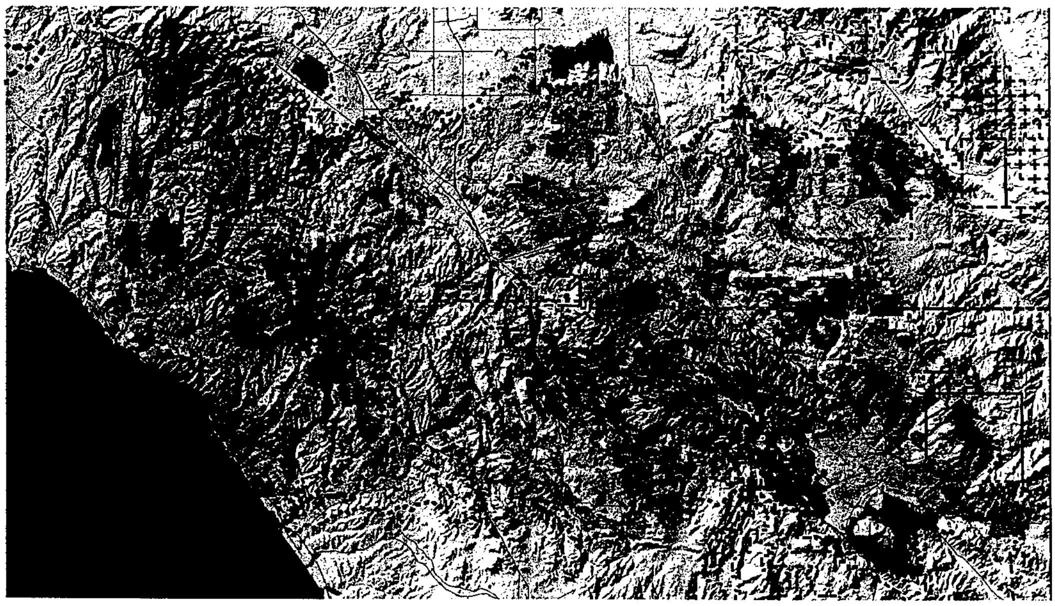
Figure 30



Runoff Curve Number: 1990+

RCN 30-45 — 87509 ha 2%
RCN 46-40 — 318416 ha 9%
RCN 61-75 — 638791 ha 18%
RCN 76-90 — 34420 ha 10%
RCN 90+ — 598507 ha 17%

Figure 31



Runoff Curve Number: Plans Build-Out

RCN 30-45 — 50338 ha 1%
RCN 46-60 — 223589 ha 6%
RCN 61-75 — 555561 ha 16%
RCN 76-90 — 549661 ha 15%
RCN 90+ — 620375 ha 17%

Figure 33

25-Year Storm Rainfall

Rainfall in Inches

0 1 3 5 kilometers
0 1 3 5 miles

land cover, existing soil moisture, roughness of the land-vegetation surface, and slope. These data are measured for each named soil series and reported in the NRCS soil surveys. A computer model developed by Julien (et al., 1993) and implemented in the raster GIS program GRASS (Construction Engineers Research Laboratories, U.S. Army Corps of Engineers) is used to simulate both overland and channel flows.

The 25-year storm of 125mm is used as the test precipitation. It is useful to define the meaning of this storm designation. Historically, rainstorms that dropped 125mm of rain or more in the Camp Pendleton region occurred in about 4% of all the years of the measurement record. This implies that they have occurred four times in any given 100-year period (not once every 25 years). Thus, the probability of a 125mm rainstorm during any year is 4%, and such a storm is called the "25-year storm." (Note that .04 and 25 are recriprocals.) The rainfall distribution of the 25-year storm precipitation is shown in figure 33. To start the simulation, this rainstorm is distributed across the drainage basin. Then a proportion of the water is removed (by infiltration) as per the RCN or the Green-Ampt model, and the remainder is routed across the landscape to the stream and then downstream past the point of measurement where discharge is measured and plotted.

Flood hydrographs for the 25-year storm and soils with medium levels of antecedent moisture were calculated for 14 of the third-order basins by the RCN model, and then analyzed statistically to extend the analysis to other third-order basins of the study area. A statistical approach to the generation of storm hydrographs is taken because the simple regression equation can be applied to any other third-order basin without following the full-scale NRCS method. The statistical relationships between change of RCN and the changes of the ratios of peak discharge to bankfull discharge and total storm discharge to bankfull discharge were excellent predictive models. As shown in figure 34, they can be used with great confidence to estimate the flood flow effects of land-use change on any of the unanalyzed third-order drainage basins.

Figure 33

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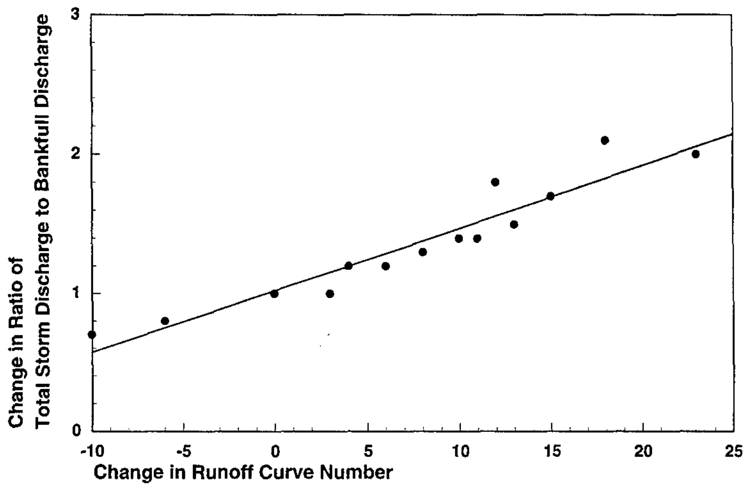
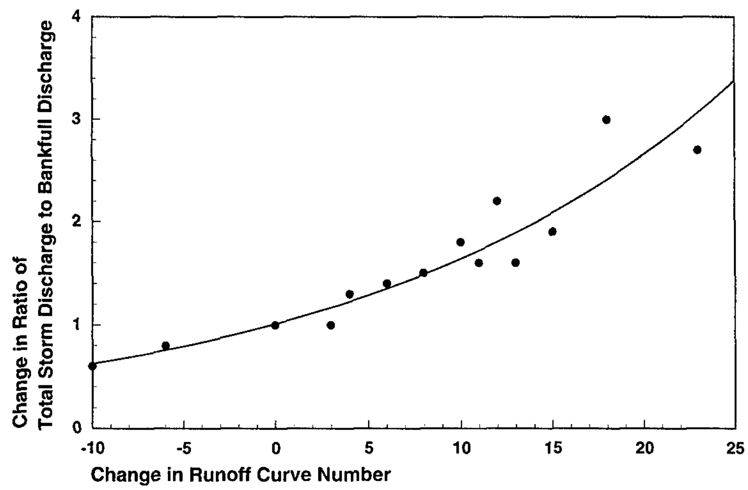
Peak discharge is the highest discharge recorded during a flood. Total discharge is the total volume of stormwater discharge over the entire hydrograph. Bankfull discharge is the discharge at bankfull flow, which is the 1.5-year flood, or the flow that has a 67% chance of being exceeded in any given year. Bankfull flow is a useful baseline discharge that is often used as a denominator to standardize hydrologic variables across basins of vastly different sizes so statistical relationships such as these can be calculated.

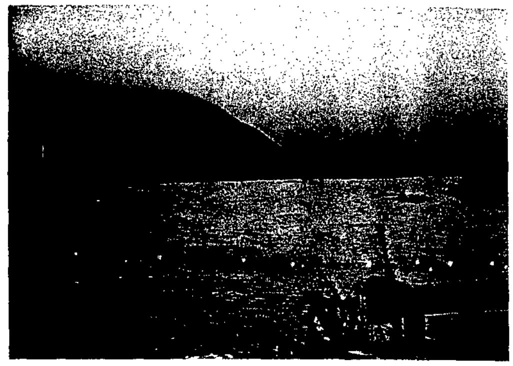
Figure 34



Change in Qtot/Qbkf = 1.02 + 0.045 * Change in RCN
$R^2 = 0.91$



Change in Qpeak/Qbkf = 1.01 * exp(0.048 * Change in RCN)
$R^2 = 0.93$



Flood hydrographs for the 25-year storm and soils with 90% saturation were calculated for the five large stream basins by the Julien (et al., 1993) model. Figures 35 through 39 show the simulated hydrographs of **1990+** land cover conditions and how they compare with hydrographs generated by the different land cover pattern predicted by the **Plans Build-Out** alternative. The hydrographs were simulated as measured in the stream channel near the river mouth, so changes in total discharge are estimates of how much additional water is lost from the terrestrial system, including Camp Pendleton, and not retained as groundwater.

According to the model simulations, both peak discharge and total discharge will increase for the San Juan, Santa Margarita, and San Luis Rey basins but will remain the same or decline for the San Onofre and San Mateo basins. The changes will be most extreme for the Santa Margarita River. There, peak discharge will nearly double and total discharge will increase by about 50%. The bulk of development in the Camp Pendleton region will take place in the Santa Margarita drainage basin, so the greatest changes in hydrological regime will occur there.

The model that simulates these hydrographs uses seven variables: a coefficient that describes the roughness of the surface over which water flow (Manning's *n*), the amount of rainfall interception by vegetation and other surfaces, the amount of rainfall stored in vegetation and above-ground structures, the moisture already in the soil, hydraulic conductivity of the soil, soil porosity, and the suction pressure at the wetting front as water moves down the soil column. In the simulations, the first three variables plus the changed extent of impermeable surface were affected by land use conversion, and the changes in the different river basins explain the mechanisms that cause different changes in the hydrographs.

The area of impermeable surface increased in a manner proportional to the area of development in each watershed, and rainfall that was not intercepted or infiltrated contributed to the volume of the flood hydrograph. The velocity of runoff was then controlled by the slope of the landscape and the roughness of the land cover. The roughness coefficient decreased in all drainage basins. The Santa Margarita River basin was predicted to be the most seriously affected by the development of buildings, paved roads and parking lots, and grasslands. The magnitude of roughness decrease in each of the watersheds was: 12.9% decrease in the Santa Margarita, 4.3% in the San Juan, 2.6% in the San Luis Rey, 1.2% in the San Mateo, and 0.3% in the San Onofre.

The relative changes in the hydrographs also follow this rank, suggesting that after the changes of runoff volume, changes in surface roughness control much of the change in flood characteristics. The changes in interception were not great (less than 1 %), and did not contribute significantly to changed hydrographs. Likewise, the storage term was not strongly affected by land cover conversion.

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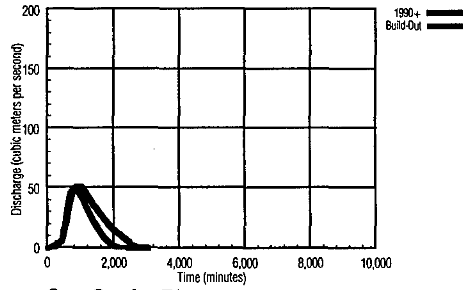
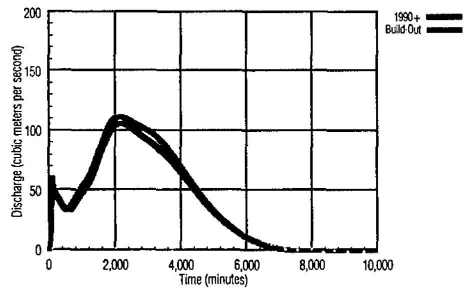
Figure 35



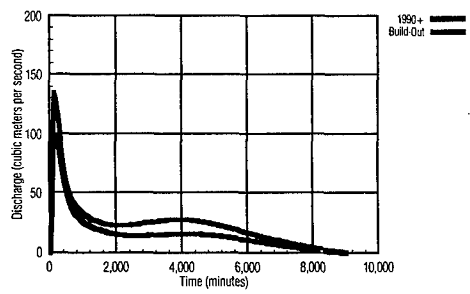
San Onofre River

Figure 36



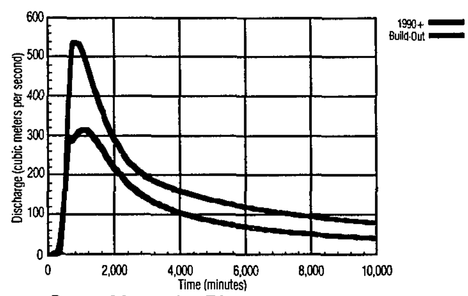
San Mateo River

Figure 37



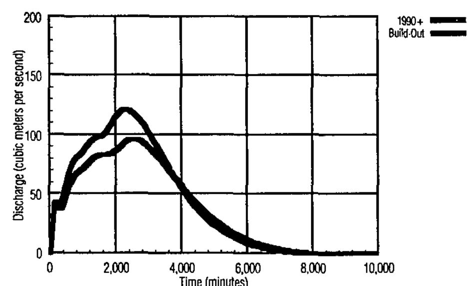
San Luis Rey River

Figure 38



Santa Margarita River

Figure 39

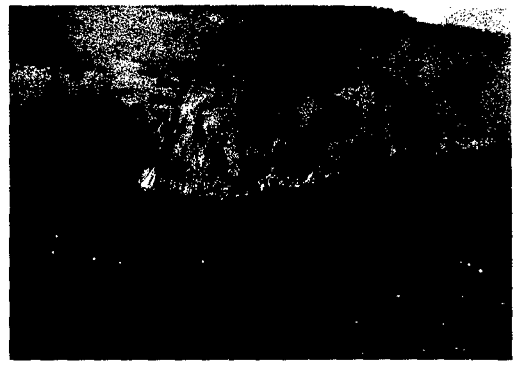


San Juan River

These predicted changes of the two flood characteristics have profound implications for MCB Camp Pendleton. The airfield is vulnerable to increased flooding because it is located in the flood plain of the Santa Margarita River. It was badly damaged by the flood of January 1993, and the threat of increased peak discharge would put it at greater risk in the future. Flood protection for the airfield and adjacent facilities is in preliminary planning and a levee is the likely preferred alternative. Any long-term solution to mitigate flood risk must take into account the increased discharge and consequently higher flood elevations caused by future upstream land conversion.

As noted earlier, Camp Pendleton's water supply is taken totally from on-base groundwater supplies. For a single 25-year storm, total discharge form the five river basins will increase by 48% between **1990+** and **Plans Build-Out**. Approximately 140 million cubic meters of *additional* water will be lost to the region's aquifers because it flows to the ocean so rapidly that it cannot infiltrate into the ground. The spreader basins in the flood plain near Lake O'Neill are designed to capture a significant amount of the Santa Margarita River's discharge under most conditions. However, they were not able to perform adequately during the 1993 flood because they were saturated and substantially filled by relatively impermeable silts transported by flood waters. An increase in the amount of water flowing through and out of Camp Pendleton necessarily means that there will be less water for aquifer recharge and, over the long term, less water available for use.

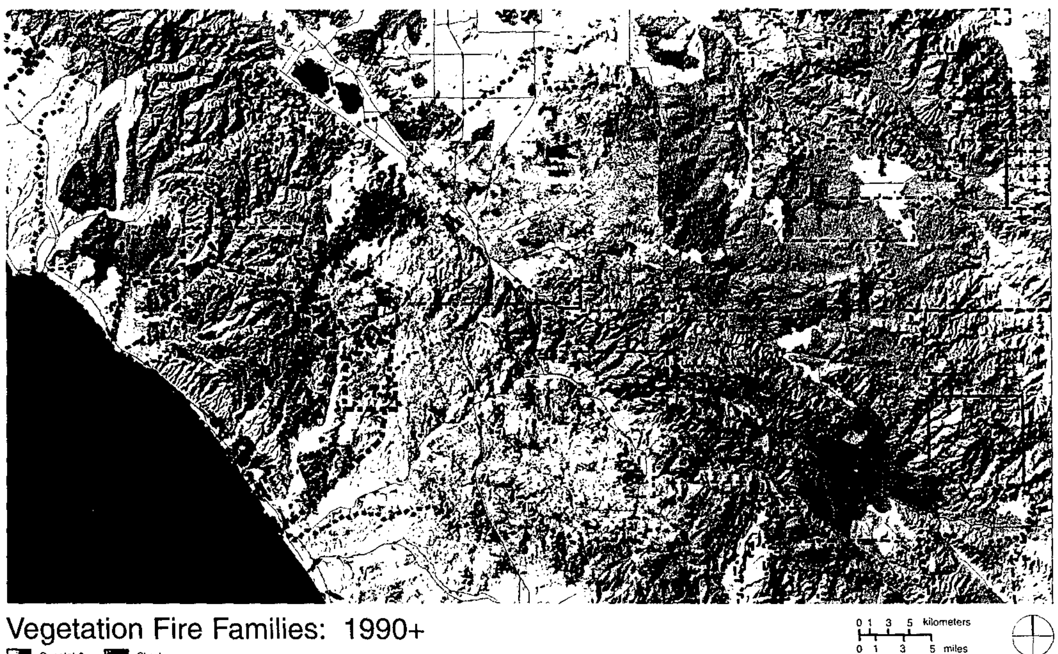
Fire



Any understanding of this landscape must include fire. Fire is a critical process in many plant communities and periodic and varied fire events are necessary for the long-term survival of native plants and habitat communities. The fire regimes that prevailed for thousands of years no longer exist. The altering of historic fire cycles, combined with land use changes and fire suppression, has resulted in a complex landscape needing active fire management.

"Fire weather" occurs from May through November, with extreme fire conditions occurring when very dry, warm Santa Ana winds blow over dry vegetation. The area's topography exacerbates the problem, because the northeast-southwest trending canyons can pull marine air inland each day as land surfaces warm, creating up-canyon winds. At night, when temperatures cool, the breezes are pulled back down-canyon and seaward. Compared to inland portions of California, the fire hazard is generally lower in the summer at Camp Pendleton because winds there generally originate from the ocean and are moisture laden.

Figure 40



Vegetation Fire Families: 1990+

Coastal & Riparian 27799 ha 1%

Shrub 1293616 ha 42 %

Fine Fuels 217317 ha 7%

Forest 112518 ha 4%

Grassland & Oak 367373 ha 12%

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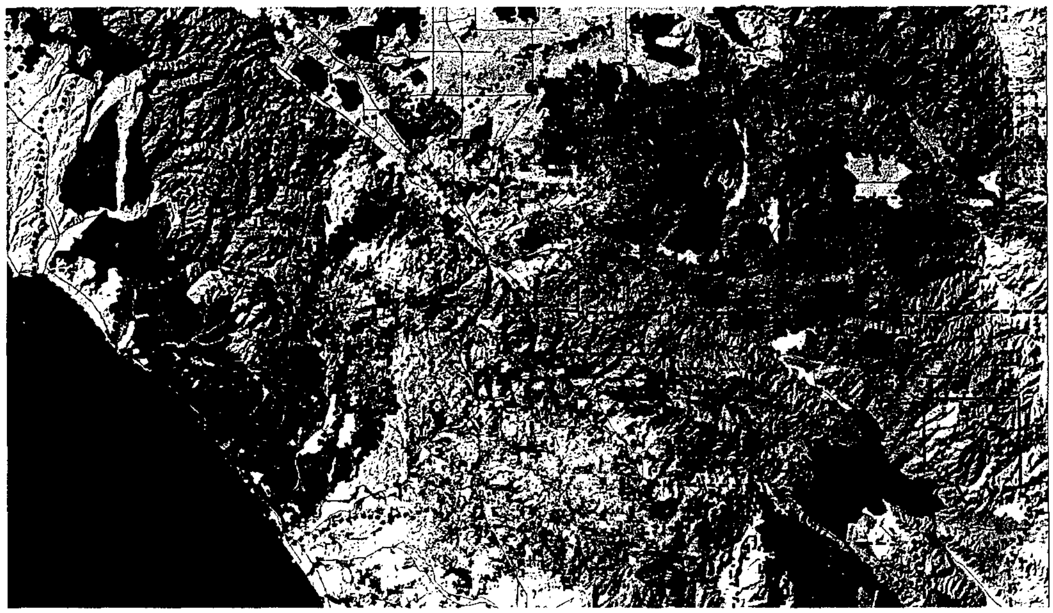


Vegetation: Fire Return Interval

Both urban development and natural communities occurring within the study area have fire management issues and concerns. The threat to life and property caused by fire is clearly understood by all homeowners. What is less understood is that periodic and varied fire events are necessary for the long-term survival of native plants and habitat communities and, in turn, the area's high biodiversity. While these positions appear at odds, they share some common land management needs.

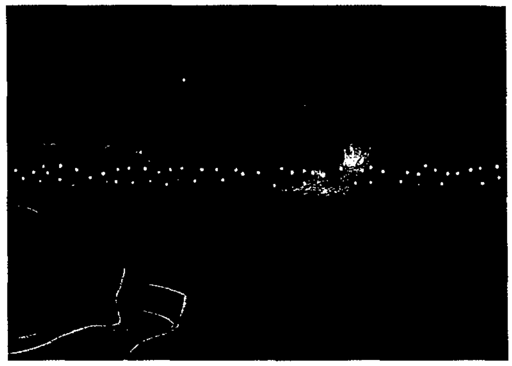
Current fire needs among natural communities vary. Some require high intensity and/or frequent fire events for successful re-generation, while other areas of sensitive populations may require protection from intense fire events. Although response to fire is variable, all of the plant communities within the area of concern have some natural adaptation to fire. Figure 40 shows the vegetation of the study area grouped by burn compatibilities, and figure 41 shows the dependence upon fire, expressed in the long-term return interval.

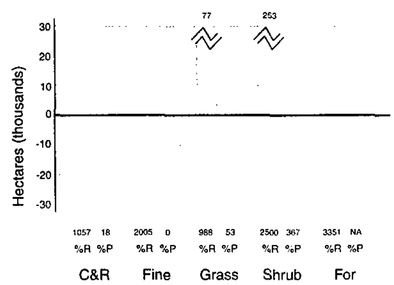
The practice of fire suppression, combined with a highly fragmented landscape of developed and undeveloped areas, has dramatically altered the historic fire regime of the region. The resulting natural vegetation patches are subject to elevated fuel loads and are highly susceptible to catastrophic fire events. These events pose the greatest threat to homeowners. In addition to elevating fuel loads, extended periods of fire supression may trigger a change from one habitat type to another. As a result, active fire supression can cause a long-term threat to homeowners, through risk of catastrophic fire, as well as to the natural environment, through succession to a new habitat community.

Figure 42 shows the fire risk area of **1990+**. Areas most at risk are small isolated patches of vegetation and residential areas in or adjacent to vegetated areas with a high proclivity to burn. These juxtapositions are common in rural residential development. Figure 43 shows the fire risk areas of **Plans Build-Out**. As seen in the bar chart in figure 44, there will be a substantial increase in fire risk to people and property, and to the natural environment in fire-prone rural residential areas.

This situation will require increased fire management planning throughout the study region. Fire is an inherently stochastic process. That is, there is variability in both the recurrence of fires and intensity of the burning process. While it is possible to describe a given vegetation type's need for fire as an average fire return interval, variability in the timing of each fire is also an important aspect for this natural process. It is, therefore, necessary to mimic this variability in preemptive controlled burnings. The use of such prescribed and managed fires to assist in the protection of life and property and to maintain habitat has the potential for meeting multiple goals within a single landscape management program.

MCB Camp Pendleton has an active fire managment plan, and its scheduled burning, when coordinated with training activities, assures the maintenance of fire-dependent habitat while simultaneously protecting property. However, fire does not recognize property boundaries. Increased risk caused by development near the base will require the communities and public land agencies surrounding Camp Pendleton to coordinate fire managment planning. Addressing the role of fire in this landscape remains a key to the future of biodiversity.





Fire Risk: Change

Figure 44

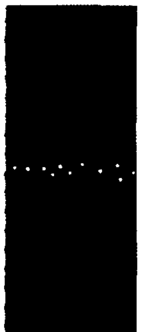
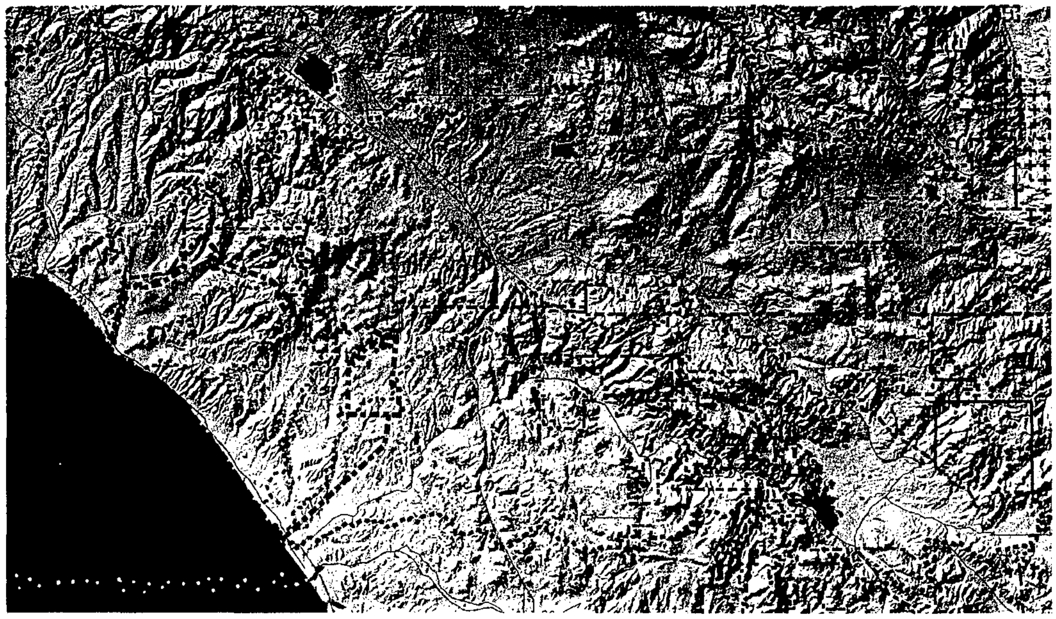


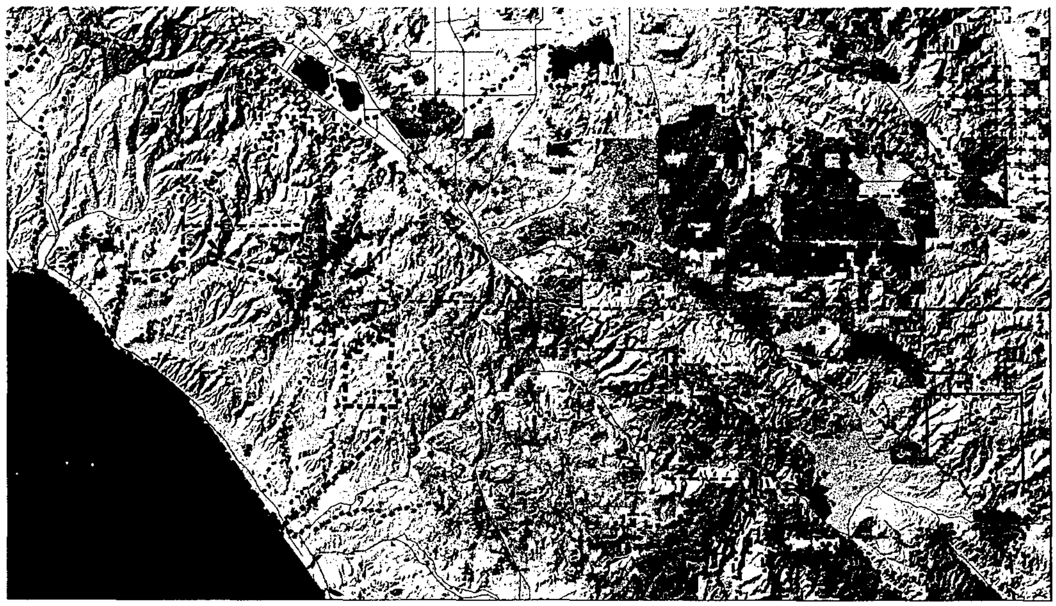
Figure 42



Fire Risk: 1990+

Coastal & Riparia	1722 ha 0%	Shrubs	21158 ha 1%
Fine Fuels	7493 ha 0%	Forest	3372 ha 0%
Grassland & Oak	14394 ha 0%		

Figure 43



Fire Risk: Plans Build-Out

Coastal & Riparian	10907 ha 0%	Shrubs	457466 ha 13%
Fine Fuels	97154 ha 3%	Forest	36143 ha 1%
Grassland & Oak	174670 ha 5%		

Figure 44

Vegetation

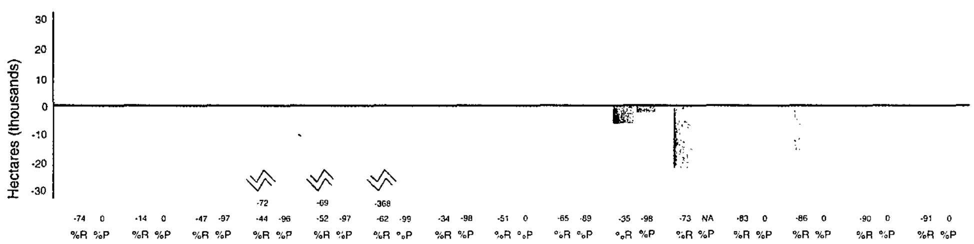
The vegetation of the study region is a result of a combination of natural conditions including climate, soil type, soil moisture, elevation, and solar aspect. It is classified by the California Natural Diversity Database/Holland code (hereafter Holland, 1986), a 5-digit numbering system which identifies and groups California plant species into 375 plant communities by majority vegetation type. Although the Holland code descriptions are detailed, it should be noted that they are not complete. For example, Coulter Pine, *Pinus coulteri*, is not found in the Holland code category for Conifer Trees; however, Coulter Pine is found in the study area and is represented in the California Wildlife Habitat Relation (WHR) model used in the assessment of species richness. The major vegetation groups in the study area are Herbaceous, Chaparral Shrubs, High Desert Shrubs, Desert Shrubs, Coastal Sage Shrubs, Great Basin Shrubs, Hardwood Trees, and Conifer Trees. The distribution of major plant communities in the study region is shown in figure 45.

While vegetation is important as its own entity within a study of biodiversity (see Davis, et al., 1995), it is also essential to understand the relationships between vegetation types and species habitats. The several measures of biodiversity –landscape ecological pattern, single species potential habitat, and species richness– all depend upon the type and distribution of vegetation.

Vegetation will be altered directly and indirectly in any alternative future. The direct changes are principally those related to the construction of new development. As was seen in the **Plans Build-Out** change bar chart, figure 16, change may directly impact several natural vegetation groups: riparian vegetation (5,000ha), oak woodland (25,000ha), mixed forest (10,000ha), sage chaparral (300,000ha) and grassland (55,000ha). In addition, considerable amounts of orchard, agriculture, and altered but non-built land will be converted to urban uses.

There are also indirect changes associated with urbanization which may impact vegetation land cover. Among these are increased avocado plantations, changes in riparian vegetation caused by increased flooding, upland vegetation changes caused by decreased soil moisture, changes caused by increased fire frequency, and vegetation changes caused by fire suppression in new developed areas. The areas where the vegetation pattern associated with **Plans Build-Out** is at risk to change are seen in figure 46.

Figure 47



Vegetation: Change

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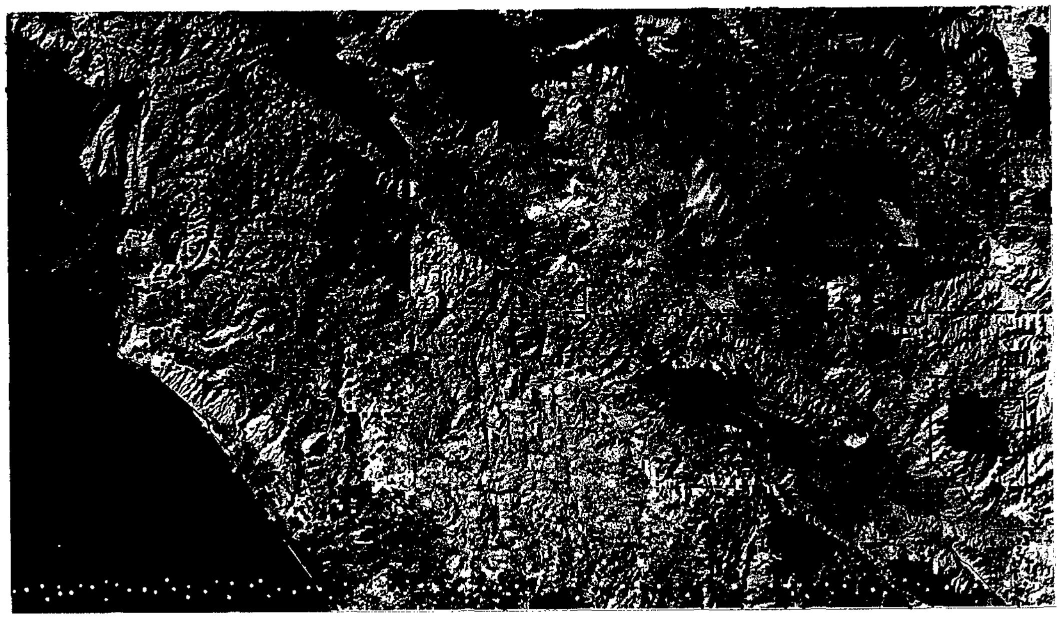
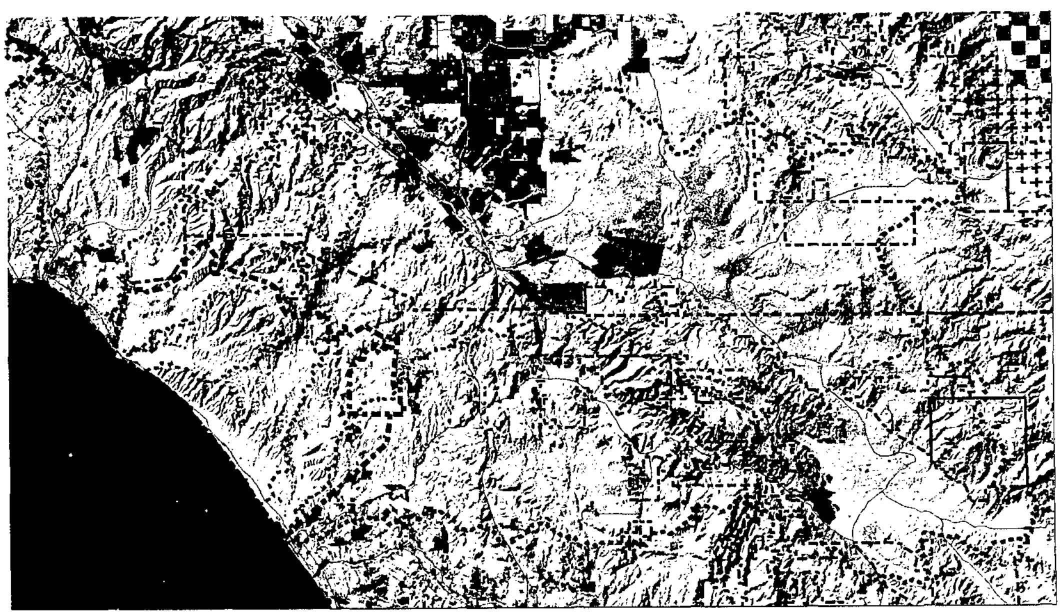


Vegetation: 1990+

Beach & Alluv. Wash 1275 ha 0%	Coastal Scrub 623777 ha 20%	Marsh 2118 ha 0%	Oak & Jun Woodland 133828 ha 4%	Agricultural 86127 ha 3%	Urban 506374 ha 16%
Dune Community 437 ha 0%	Grassland 234209 ha 8%	Riparian Forest 16274 ha 1%	Mixed Woodland 157454 ha 5%	Row Crops 6367 ha 0%	Disturbed 10352 ha 9\0%
Fan Scrub 14333 ha 0%	Chaparral Sage/Scrub 1123354 ha 36%	Riparian Woodland 8444 ha 0%	Orchard 82655 ha 3%	Pasture 46506 ha 1%	Water

Figure 46



Vegetation Risk: Plans Build-Out

Change in Soil Moist 6417 ha 0%	Urban Residential 338667 ha 9%
Fire Supression 623997 ha 17%	
Ch in l Moist & Fire Suppr 23110 ha 1%	

Figure 47

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The focus of landscape ecology is the spatial relationships between structural and functional elements of the land. Any type of landscape at any scale can be described as a mosaic: a background matrix and patches connected by corridors. For instance, a matrix can be uniform to fragmented, continuous to perforated, and aggregated to dispersed. Patches can vary from large to small, elongated to round, and convoluted to smooth. Corridors vary from wide to narrow, and meandering to straight. The edges that separate these spatial elements also vary widely in shape and dimension.

The following elements form the landscape ecological pattern in the study region:

Contiguous natural vegetation: areas larger than 500ha which currently form the pattern matrix and the principal source of biodiversity;

Isolated natural vegetation: areas less than 500ha which form natural patches and stepping stones surrounded by disturbed or built landscape;

Natural edges: a 90m wide band that extends into the contiguous and isolated natural vegetation from disturbed areas;

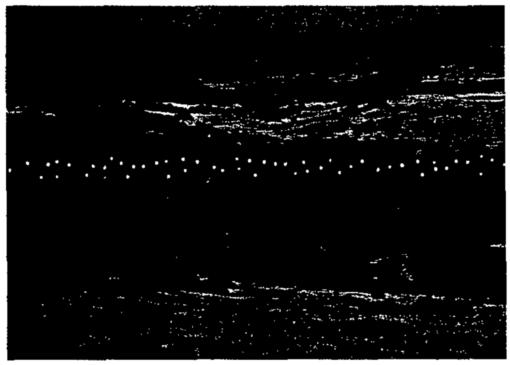
Stream corridors: linear features up to 90m across which can connect patch elements;

Disturbed landscape: primarily agriculture and military impact zones, which have repeatedly disturbed vegetation;

Built landscapes: all urban land and roads;

Water.

The evaluation of the landscape ecological pattern presents a hypothesis that there are spatial landscape patterns that will conserve the majority of natural processes in any landscape or major portion thereof. These patterns will not protect every species, every nutrient concentration, or every water body, but conserving the spatial pattern will maintain the most important attributes of the ecosystem. Evidence found over the past several years in the fields of landscape ecology, conservation biology, forestry, and others suggest that spatial pattern is an integral factor in natural processes (Harris 1984, Franklin 1993, Soule 1987, Mefe and Carroll 1994).



The patch-corridor-matrix model proposes that an ecologically viable landscape must contain four indispensable patterns to provide for critical landscape functions:

1) Large patches of natural vegetation which protect the species richness of a landscape;

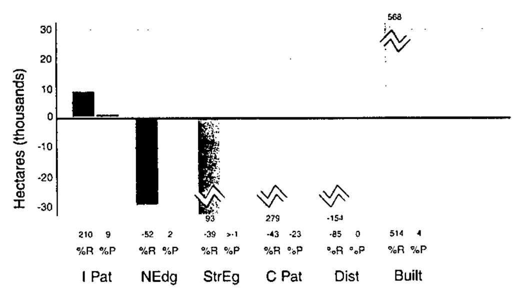
2) Species movement connectivity between large patches in the form of wide corridors or clusters of small natural-vegetation patches;

3) Vegetated corridors along major streams and rivers which allow for species movement and a wide range of ecological benefits not otherwise obtained such as erosion control, nutrients, and fish habitat; and,

4) Small patches scattered across a less suitable matrix which provide key ecological benefits such as rare species habitats and stepping stones for movement.

The landscape ecological pattern in **1990+** is shown in figure 48. In the region of Camp Pendleton, the matrix is composed of several large natural areas, many of which include the Cleveland National Forest and other public lands. There are large concentrations of "disturbed-urbanized" land as well as areas of "disturbed-natural" land in agriculture and military use. The landscape still retains a set of natural patches and smaller "stepping stones," connected by stream and riparian vegetation corridors. These can (still) be the basis of a conservation pattern with links across the study region.

The landscape ecological pattern of **Plans Build-Out** is shown in figure 49. There will be two major consequences of this potential change. The first, which can be seen in the change bar chart in figure 50, is the large conversion of natural vegetation habitat into urban uses. About 90,000ha of riparian corridor habitat is threatened, and these are the most significant elements contributing to the connectivity of the landscape ecological pattern. The second consequence, which is perhaps of greater significance to the region's biodiversity, is the inversion of the landscape ecological pattern of **1990+** from one of urban patches in a large well-connected natural matrix to a future pattern of fragmented natural patches in an urbanized matrix. All aspects of biodiversity that currently rely on larger interconnected natural habitat will be diminished.



Landscape Ecological Pattern: Change

Figure 50

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Figure 50

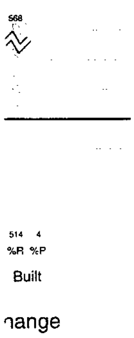
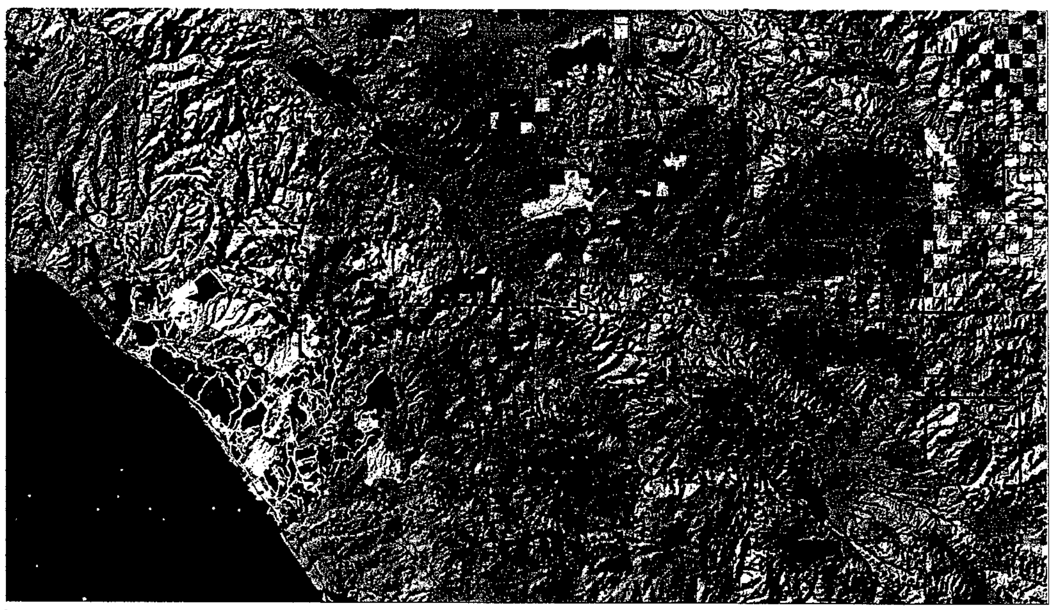


Figure 48

Landscape Ecological Pattern: 1990+

Isolated Nat Veg 54657 ha 2%	Contiguous Nat Veg 1495508 ha 42%	Water 506628 ha 14%
Natural Edges 251397 ha 7%	Disturbed Landscapes 407106 ha 11%	
Stream Corridors 516492 ha 14%	Built Landscapes 342046 ha 10%	

Figure 49



Landscape Ecological Pattern: Plans Build-Out

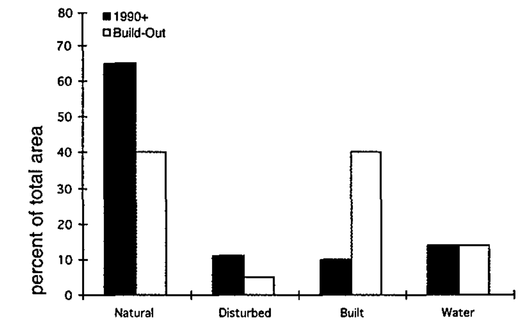
Isolated Natural Veg 109798 ha 3%	Contiguous Nat Veg 845565 ha 24%	Water 511648 ha 14%
Natural Edges 164583 ha 5%	Disturbed Landscapes 180457 ha 5%	
Stream Corridors 324904 ha 9%	Built Landscapes 1436879 ha 40%	

The natural patches grouped by size for **1990+** and **Plans Build-Out** are shown in figures 51 and 52. Figures 53 and 54 represent analysis conducted on the entire study area. The changes indicated in the bar charts show a dramatic drop in natural cover, from 65% to 40% of the total area. "Built" areas increased from 10% of the region to 40%.

The structural composition of the natural area has also changed. Significantly, the area of extremely large natural patches (>10000ha) in **1990+** is halved by **Plans Build-Out**. These large patches, which form the matrix of the landscape, are particularly important to the long term viability of many species. In addition, the remaining natural landscape is much more fragmented, consisting of smaller patches with a greater percentage of human influenced edge. The amount of edge, as expressed as a percentage of the total natural area, has increased, thereby reducing the important interiors of natural patches.

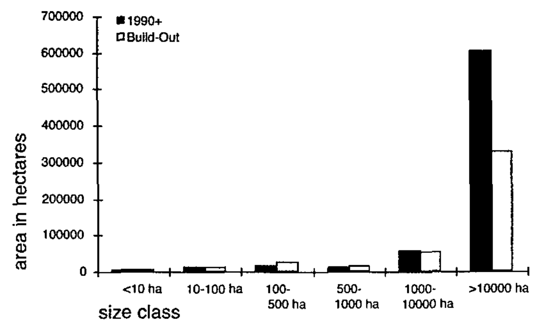
Naturally vegetated stream corridors are also shown to be at great risk. Up to 40% of the corridors present in **1990+** are threatened in the **Plans Build-Out**. This has important implications both to water quality and to connectivity of the landscape. The changes to the natural landscape in terms of total area, patch size class distribution, fragmentation and edge conditions all have serious negative consequences.

Figure 53



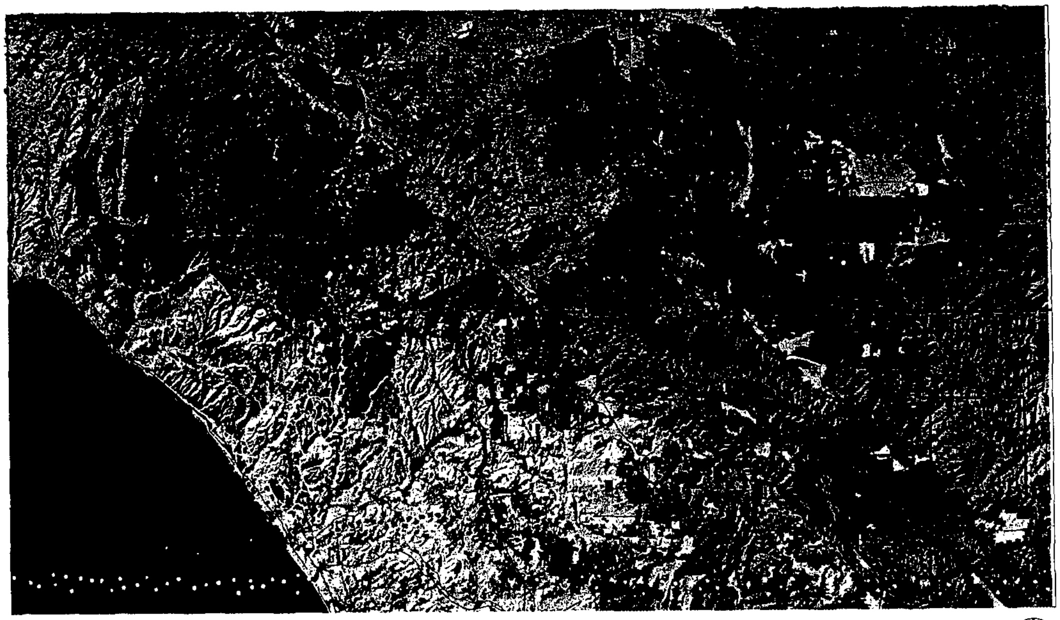
Percent of Total Area by Cover Class

Figure 54



Area of Natural Patches by Size Class

Figure 51

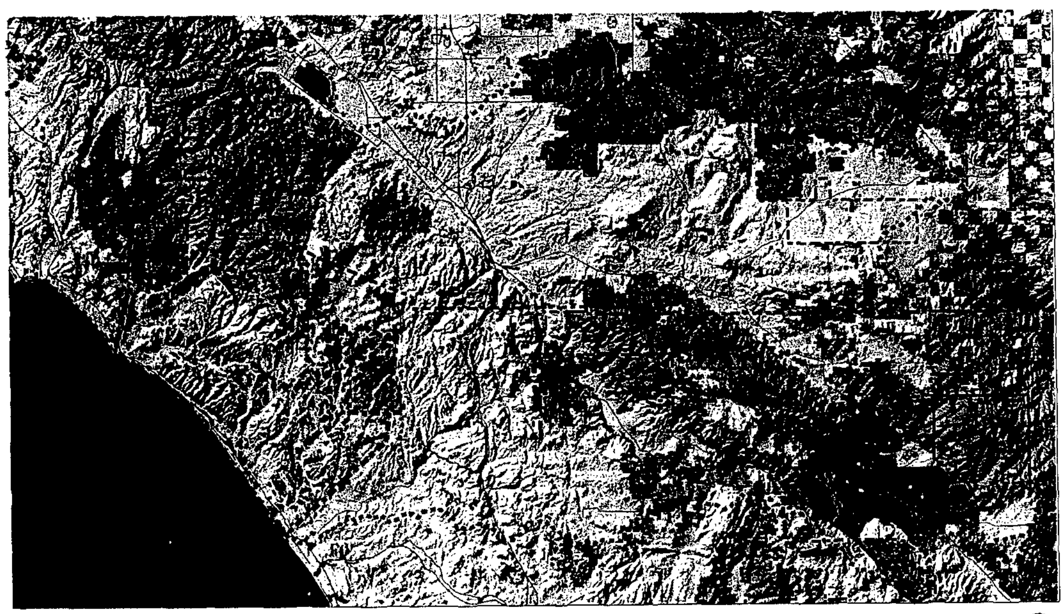


Patch Size: 1990+

< 10ha — 14470 ha 0%
10 to 99ha — 36336 ha 1%
100 to 499ha — 48917 ha 1%
500 to 999ha — 30476 ha 1%
1000 to 10000 — 180402 ha 5%
> 10000ha — 2007453 ha 56%
Watershed Boundary
Camp Pendleton

0 1 3 5 kilometers
0 1 3 5 miles

Figure 52



Patch Size: Build-Out

< 10ha — 8977 ha 0%
10 to 99ha — 38608 ha 1%
100 to 499ha — 85471 ha 2%
500 to 999ha — 47908 ha 1%
1000 to 10000ha — 172581 ha 5%
> 10000ha — 1086796 ha 30%
Watershed Boundary
Camp Pendleton

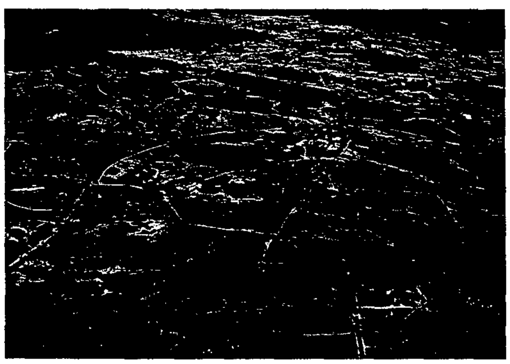
0 1 3 5 kilometers
0 1 3 5 miles

The potential habitat model for each wildlife species has been formatted according to standards for the development of Habitat Suitability Index (HSI) models of the U.S. Fish and Wildlife Service (USFWS, 1981). The HSI models are an outgrowth of the Habitat Evaluation Procedures (USFWS, 1980). The HSI format emphasizes the quantitative relationships between environmental variables and habitat suitability. HSI models focus on spatially explicit habitat data, which include vegetation type, stand age, stand density, percent cover, vertical and horizontal structure, patch size, patch configuration, edge, juxtaposition of plant community types, disturbance, elevation, aspect, soil, special features and other spatially explicit factors. Behavioral data with spatial implications are also incorporated into each model.

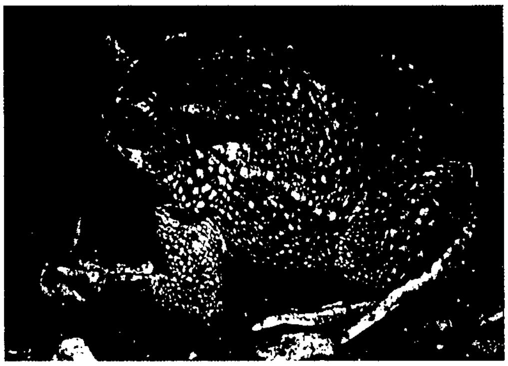
Each potential habitat model was generated from numerous literature sources and personal communications with wildlife scientists. All models were reviewed by Camp Pendleton staff biologists who were familiar with the species of concern and the ecology of southern California. Additional

reviews of some models were provided by biologists specializing in a particular species. The models vary in level of precision due in part to varying availability of life history and habitat-related information. Each species' potential habitat map based on HSI data delineates the estimated possible habitat for that species. The later impact map delineates the estimated changes to the habitat based on development and conservation scenarios.

The list of species for which potential habitat conditions were modeled was prepared by Camp Pendleton biologists and the research team. The use of all major plant community types found in the study area is represented by at least one selected species. The selected species are: the arroyo southwestern toad, the orange-throated whiptail lizard, the coastal cactus wren, the least Bell's vireo, the California gnatcatcher, the western bluebird, the brown headed cowbird, the gray fox, the mule deer, and the California cougar.



The Arroyo Southwestern Toad



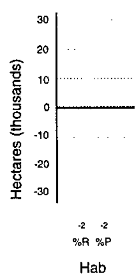
The arroyo southwestern toad, *Bufo microscaphus californicus*, is sensitive to changes in hydrology and riparian vegetation. It is a federally listed endangered species. This species was described by Sweet (1991) as an animal specialized for life in an intrinsically unstable habitat. Breeding sites and areas for adults are drainages of an intermediate size range, typically third- or fourth-order streams in decomposed granite, or fifth-order streams in sedimentary rock where stream gradients are low. Bars and low sandy terraces bordering the stream channel are important as are higher terraces of fine alluvium. Summer stream flow or the persistence of shallow pools until at least July is essential.

Adult arroyo toads feed almost exclusively on a variety of insects. Juvenile toads feed on small insects such as ants, beetles, and ladybugs. Tadpoles are detritus feeders, gleaning organic matter from the sand or gravel substrate.

Adult arroyo toads are primarily nocturnal, and thus darkness is one component of cover. They remain buried during the day and emerge nightly from late March to early July. The tadpoles frequent open bars and flats along the stream edge. Algae mats that form in quiet shallows are an important cover type.

Breeding pools for the arroyo southwestern toad require minimal stream current, a majority of pools less than 0.3m deep, pool substrate of sand and gravel with virtually no silt, and a gently sloping shoreline or central bar nearby.

There will be few changes in Arroyo Toad habitat that are directly caused by development between **1990+** and **Plans Build-Out**. This is because of the relative difficulty of building in riparian corridors and existing protective regulations. However, there may be important indirect impacts due to decreasing soil moisture in upland areas and increased flooding and scouring of riparian zones at lower elevations.



Arroyo Toad Potential Habitat: Change

Figure 57

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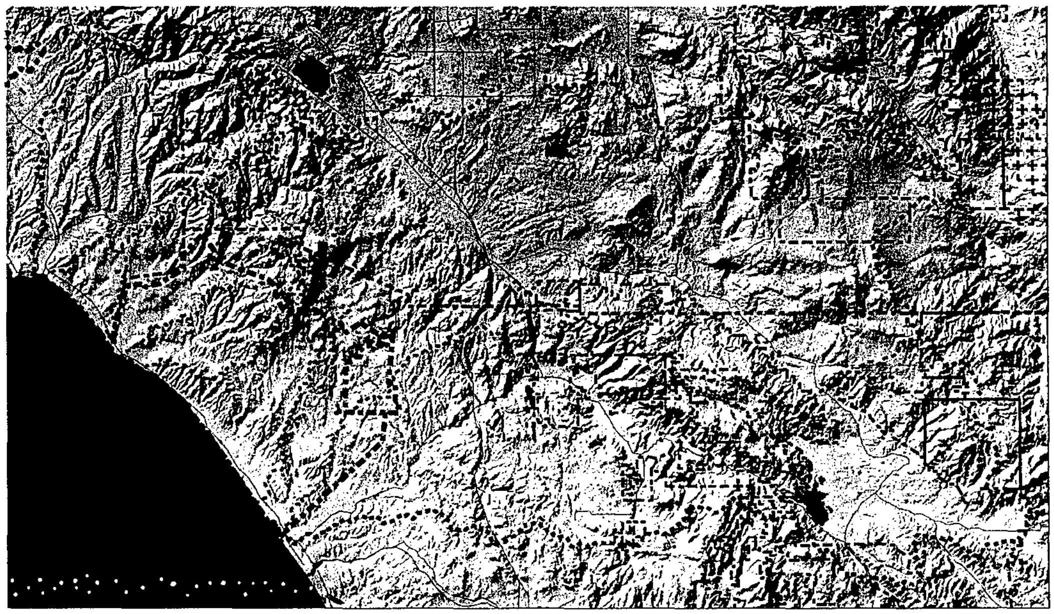
Figure 55



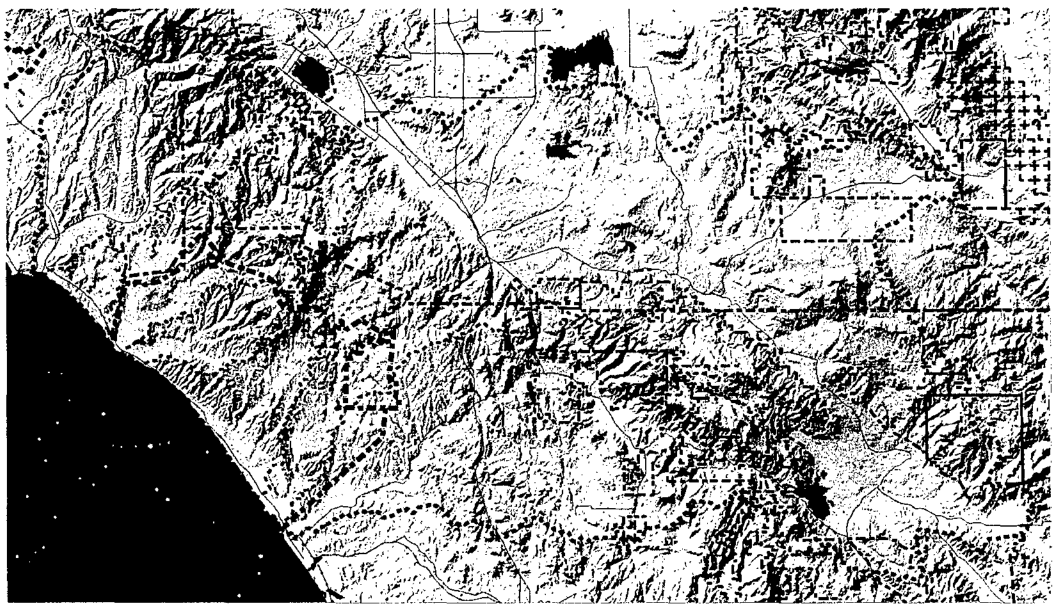
Arroyo Southwestern Toad Potential Habitat: 1990+

0 1 3 5 kilometers
0 1 3 5 miles

Potential Habitat
3848 ha 0%

Residual
3570199 ha 100%

Figure 56



Arroyo Southwestern Toad Potential Habitat: Plans Build-Out

0 1 3 5 kilometers
0 1 3 5 miles

Potential Habitat
3549 ha 0%

Residual
3569959 ha 100%

New Habitat
241 ha 0%

Lost Habitat
299 ha 0%

Figure 57

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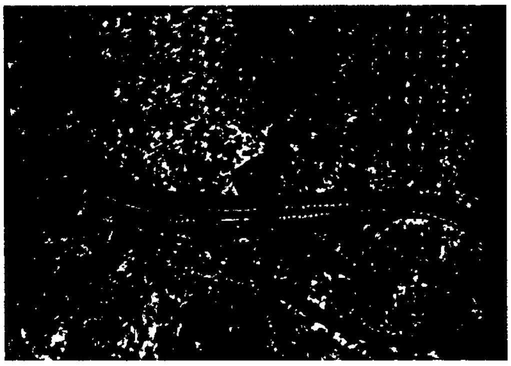
The Orange-Throated Whiptail Lizard



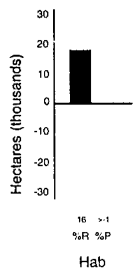
The orange-throated whiptail lizard, *Cnemidophorus hyperythrus beldingi*, is a California species of concern. It has specific soil requirements and is dependent upon a single species of termite as its principal food source. The orange-throated whiptail inhabits a variety of plant community types that thrive in loose, well-drained soils including chaparral, coastal sage scrub, and coastal strand vegetation (Bostic, 1964), and oak woodland, grassland and riparian communities in Orange County (Rowland, 1992). They are primarily found at elevations below 850m. Whiptail populations are closely associated with their principal food source, western subterranean termites, *Reticulitermus hesperus*, and the habitat that supports them. Bostic (1966) estimated that termites comprise 85% of the whiptail's diet, approaching 100% from September through November.

The whiptail relies on its striped color pattern for camouflage, which is particularly effective when the whiptail is motionless in the shade beneath overhead structure. Perennial shrub cover is important for adults, hatchlings, and juveniles. Preferred cover species include *Eriogonum spp.* and *Salvia* (Rowland, 1992).

Females deposit their eggs in thick patches of annuals and grasses. This cover type may afford the best protection for hatchlings or provide the structure that supports food of the appropriate size. Average home range size for adult males is $42m^2$ and $300m^2$ for adult females.

There will be a shift in the spatial pattern of lizard habitat between **1990+** and **Plans Build-Out**, as seen in figures 58 and 59. Serious losses will occur in the Temecula Valley because of the conversion of potential habitat to single family residential use. However, there may be modest gains in the foothills of San Diego County as rural residential development expands, contingent upon a parallel increase in the termite population.

Figure 60



Whiptail Lizard Potential Habitat: Change

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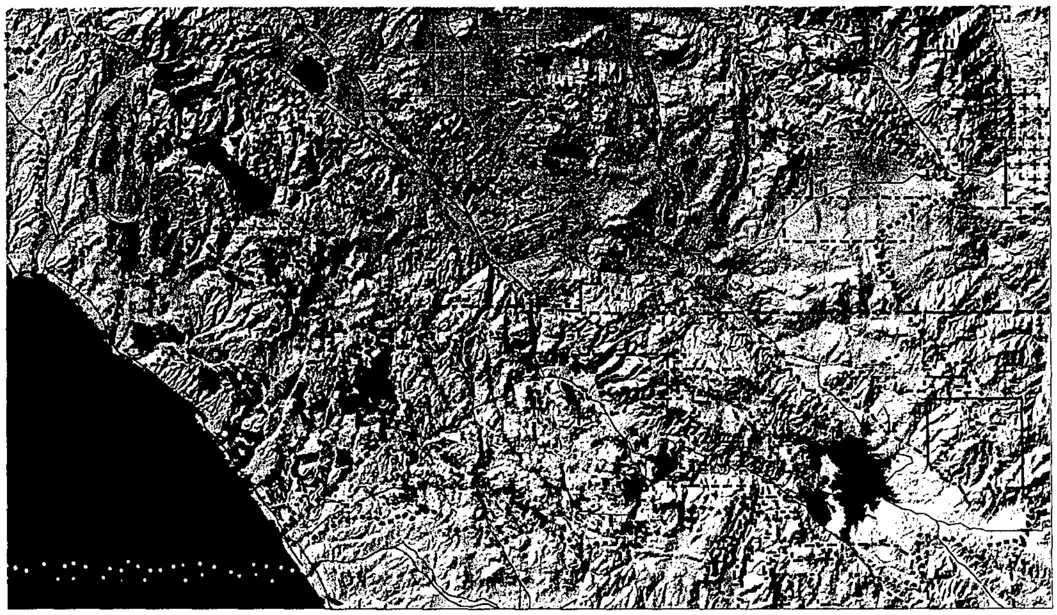
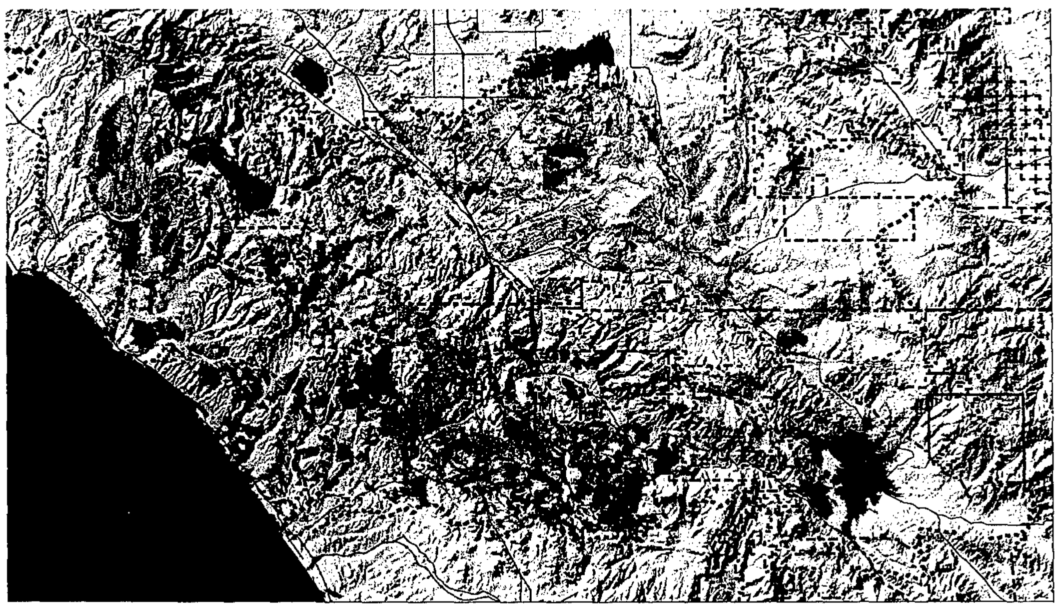
Figure 58



Orange-Throated Whiptail Potential Habitat: 1990+

Figure 59



Orange-Throated Whiptail Potential Habitat: Plans Build-Out

Figure 60

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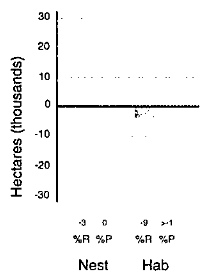
The coastal cactus wren, *Campylorhynchus brunnecapillus sandiegensis*, has been proposed for federal listing as a threatened species. Its preferred habitat is dense coastal sage scrub 0.3 - 1.8m in height with patches of *Opuntia* cactus. The coastal cactus wren is predominately an insectivore foraging in vegetation and on the ground for a variety of insects including caterpillars, moths, and grasshoppers.

Opuntia is used almost exclusively as structure for the construction of breeding and roosting nests. Most nests are constructed between 1 - 2.5m above the ground surface and have been observed as high as 5m above ground level. The spines of *Opuntia* deter numerous predators from the breeding and roosting nests cactus wrens construct in these species. During the hottest days of early summer, cactus wrens were observed by the Andersons (1973) in the shade of mesquite trees, creosote bush, and palo verde trees. The cactus wren's coloration provides protection when it is away from the nest or the roost while foraging in the shrub layer or on the ground.

Cactus wrens establish resident territories and maintain them for life. Territories are utilized for mating, nesting, brooding, and feeding and range in size from 0.5 - 2ha.

The greatest concentration of remaining habitat is, and will continue to be, on MCB Camp Pendleton. About 10% of the region's remaining wren habitat (5,000ha) will be lost in **Plans Build-Out**.



Cactus Wren Potential Habitat: Change

Figure 63

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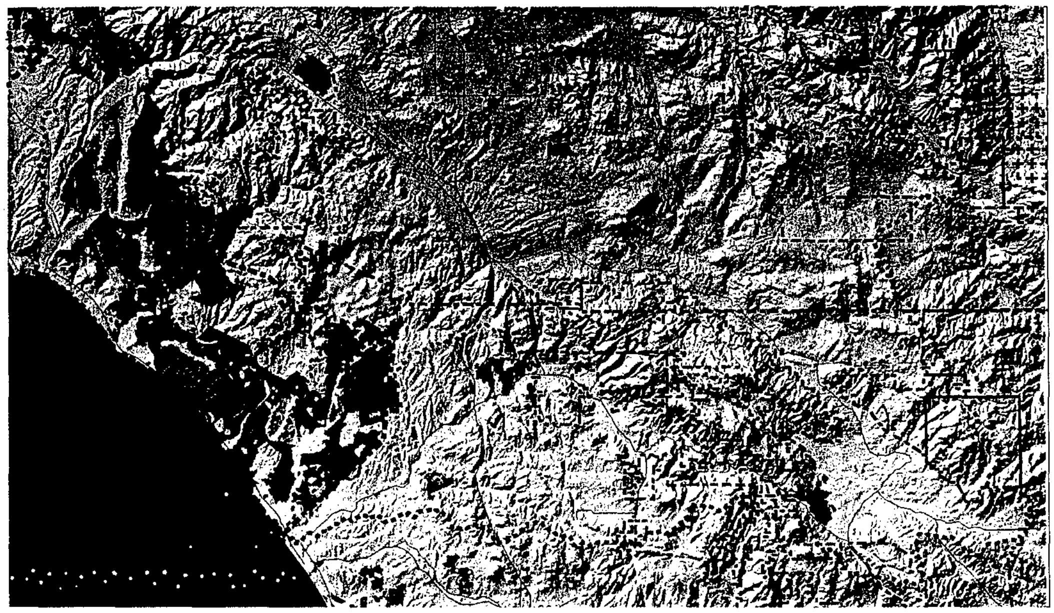
Figure 61



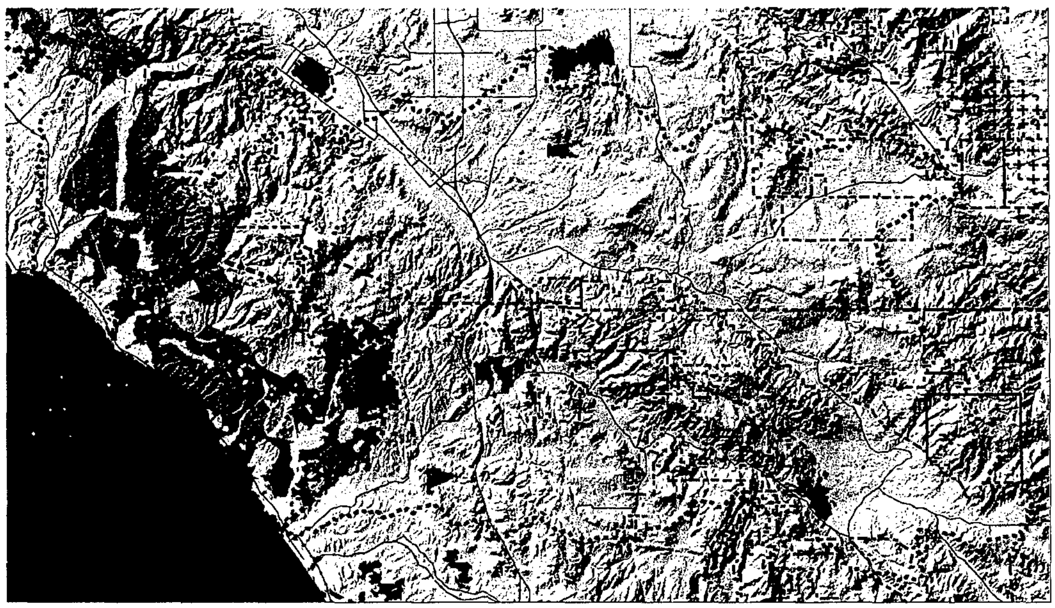
Cactus Wren Potential Habitat: 1990+

Nesting Habitat
3321 ha 0%

Potential Habitat
266056 ha 7%

Residual
3304670 ha 92%

Figure 62



Cactus Wren Potential Habitat: Plans Build-Out

Nesting Habitat
3291 ha 0%

Lost Habitat
36353 ha 1%

Potential Habitat
229733 ha 6%

Residual
3298167 ha 92%

New Habitat
6503 ha 0%

Figure 63

ange

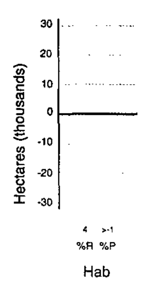
The Least Bell's Vireo

The least Bell's vireo, *Vireo bellii pusillus*, is a federally listed endangered species sensitive to changes in riparian vegetation. Preferred habitat for this species is dense willow-dominated riparian habitat with lush understory vegetation (USMC, 1994) that is in high quality 5 - 10 year-old early succession stage (Franzreb, 1989).

The least Bell's vireo is predominately an insectivore. During the early and mid portion of the nesting season most foraging occurs in the vicinity of the nest site, predominately in willow, *Salix spp.*, Both high and low shrub layers are used as foraging substrate. These birds use non-riparian habitats occasionally and will travel an average of 15 m to forage. Birds using non-riparian areas for foraging tend to have territories in the narrowest sections of riparian habitat (Kus and Miner, 1987).

A low, dense shrub layer is considered essential for nesting (Franzreb, 1989), and a large degree of vertical stratification is preferred. Willow are the most commonly used vegetation for this need. Plant species used for nesting and foraging include the California wild rose, *Rosa california,* and coastal live oak, *Quercus agrifolia.* Most nest sites are located near the edges of thickets. Nest height on average is 1m above the ground (Regional Environmental Consultants, 1988). Males are site tenacious and return to the same site to nest in succeeding years. Regional Environmental Consultants (1988) reported an average territory size of about 0.8ha.

Most of the current habitat is concentrated on Camp Pendleton and in the foothills of southern Orange County. This pattern will remain through **Plans Build-Out**, largely because of riparian zone management in Camp Pendleton.



L.B. Vireo Potential Habitat: Change

Figure 66

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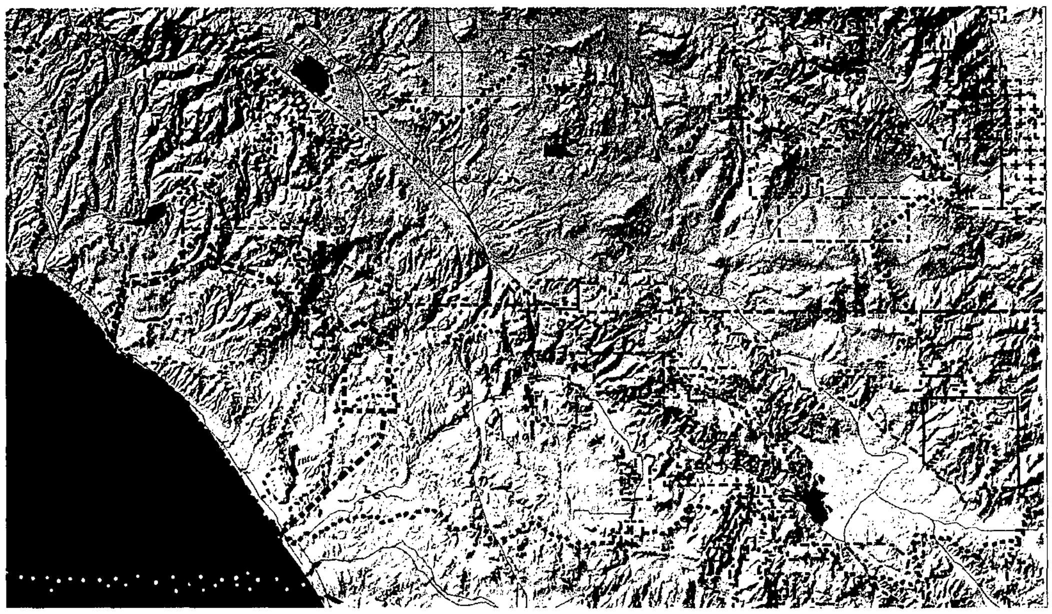
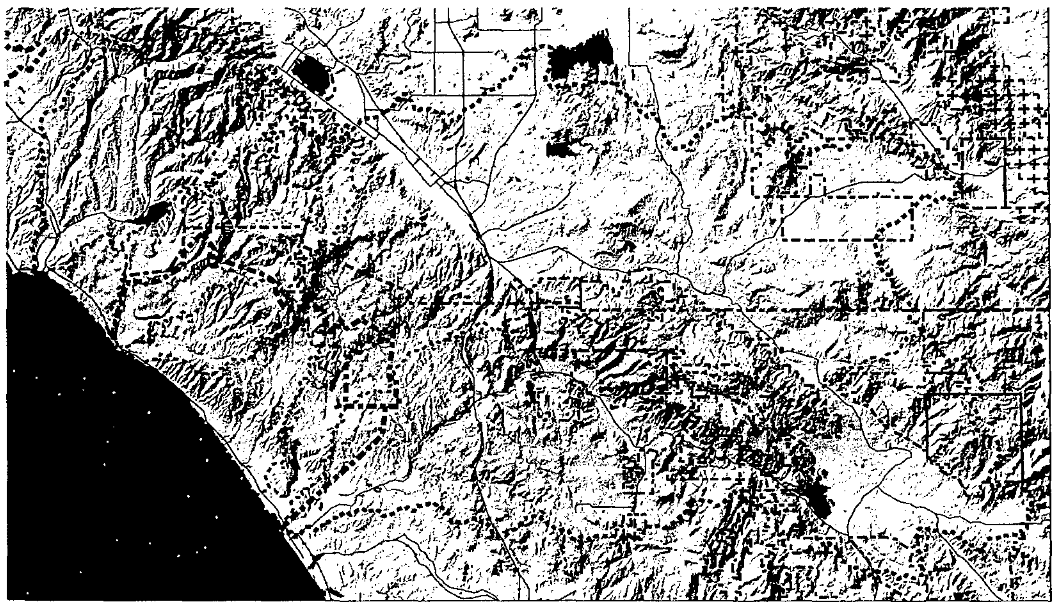
Figure 64



L. B. Vireo Potential Habitat: 1990+

Figure 65



L. B. Vireo Potential Habitat: Plans Build-Out

Figure 66

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The California Gnatcatcher

The California gnatcatcher, *Polioptila californica californica*, is a federally listed threatened species dependent upon coastal sage scrub. An estimated 94% of the existing population resides below 250m in elevation (Atwood, 1990) and sub-populations in the maritime zone appear to be more stable than those in interior coastal and transition zones.

The California gnatcatcher is an insectivorous species. It feeds on arthropods gleaned from California sagebrush *Artemisia californica* and flat-topped buckwheat *Eriogonum fasciculatum*. Gnatcatchers require large patches of coastal sage scrub. Tattersall (1988) noted that gnatcatchers preferred coastal sage scrub that had been burned eight or nine years previously. Atwood's (1990) observation is that gnatcatchers avoid dense and/or tall stands of coastal sage scrub.

The California gnatcatcher utilizes a variety of coastal sage scrub plant species with structural characteristics that will support a nest (Mock, 1993). Most nests are constructed less than 1m off the ground. The California gnatcatcher maintains a year-round territory within a home range during the breeding session (Mock, 1993). Mock (1993) also noted that territories are frequently defined by landscape features such as ridge lines, trails, and breaks in plant communities. Breeding home ranges varied from 2 - 20ha and winter home ranges may expand by an estimated 70%. These ranges tend to be smaller near the coast and larger in the drier, sparser inland areas.

The existing stands of California gnatcatcher habitat are in southern Orange Country and on Camp Pendleton. The concentrations are located in coastal zone and foothills areas on Camp Pendleton, which are managed for military training, and Orange County in areas that are being considered for protection under several conservation plans. **Plans Build-Out** threatens about half of the present 300,000ha.

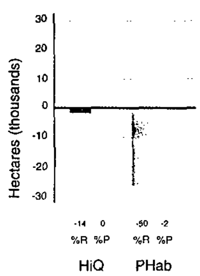

Figure 69

Gnatcatcher Habitat: Change

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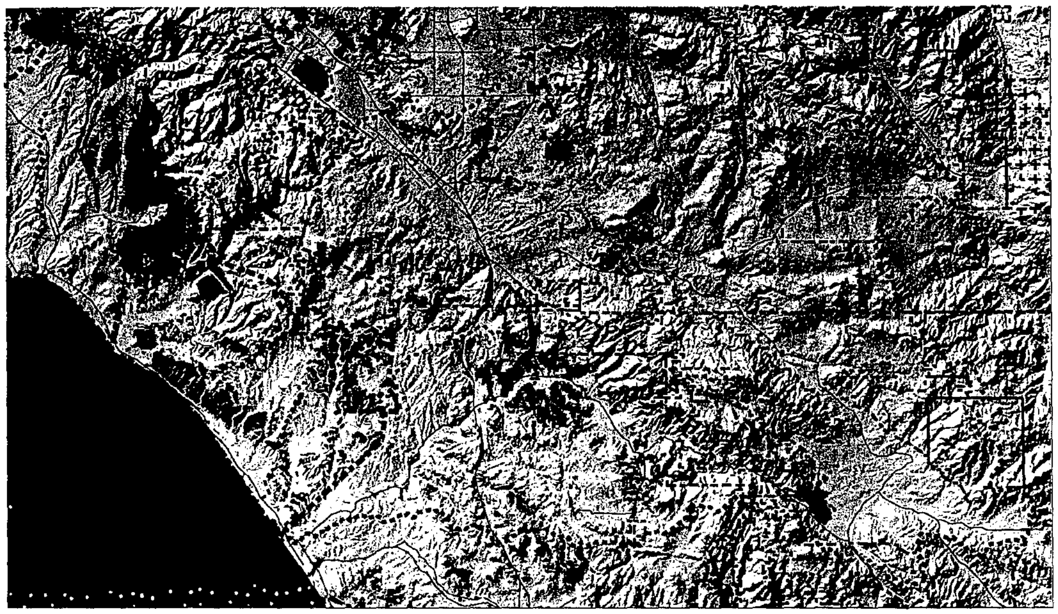
Figure 69

Figure 67



Gnatcatcher Potential Habitat: 1990+

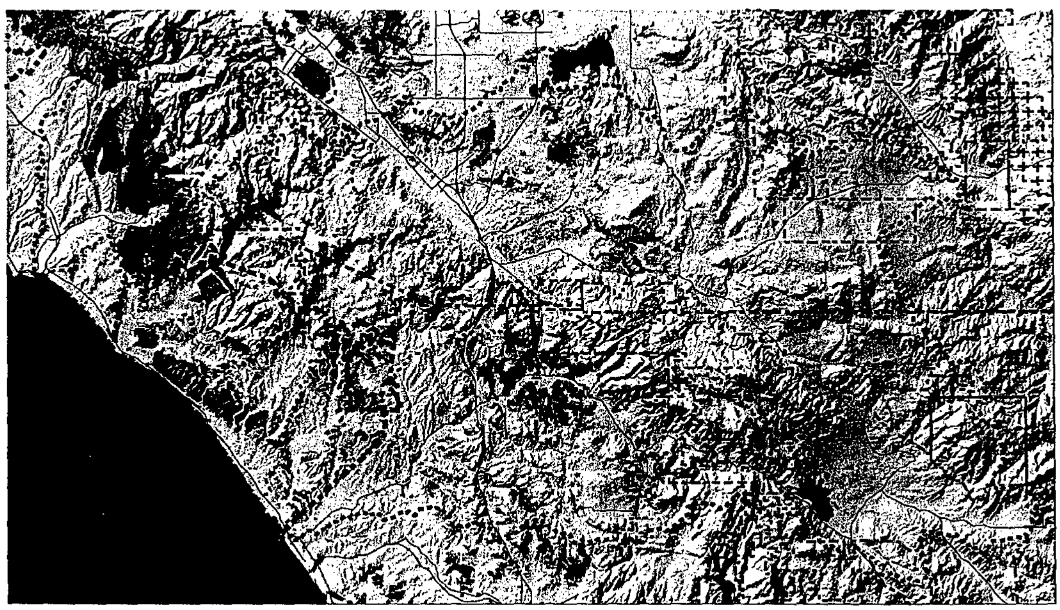
0 1 3 5 kilometers
0 1 3 5 miles

High Quality Hab
70844 ha 2%

Potential Habitat
226153 ha 6%

Residual
3277009 ha 92%

Figure 68



Gnatcatcher Potential Habitat: Plans Build-Out

0 1 3 5 kilometers
0 1 3 5 miles

High Quality Hab
56970 ha 2%

Lost Habitat
118489 ha 3%

Potential Habitat
121578 ha 3%

Residual
3273463 ha 92%

New Habitat
3546 ha 0%

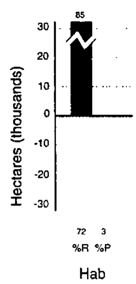
The Western Bluebird

The western bluebird, *Sialia mexicana*, is dependent upon savanna and grassland habitats that require periodic fire for maintenance. Preferred habitat is open grassland, farm or range land with sufficient tree and shrub cover for nesting and perching. Western bluebirds also occupy oak woodland, pine parkland, and cleared areas within forest stands and transition zone forests. Like all secondary cavity nesting birds, bluebird populations are limited by the availability of suitable nesting sites. Holes in trees, frequently dead snags excavated by woodpeckers, are preferred natural nesting sites. Nest cavity heights vary from 2 - 5m above ground level. The nest cavity provides both adults and young with cover during the breeding season. Bluebirds will readily use nest boxes in areas devoid of natural cavities but where other habitat components are present.

The western bluebird is predominately an insectivore. Bent (1949) described the bluebird's diet as 92% animal and 8% vegetable. Typical insects in the diet include grasshoppers, beetles, ants, wasps, flies, and caterpillars. Vegetable items include small fruits such as currants, grapes, elderberries, and mistletoe.

Bluebirds maintain a territory used for mating, nesting, and feeding. Territories tend toward a round or elliptical configuration. Mean territory size for western bluebirds in Arizona is reported as 0.4ha. Bluebirds utilize a keen sense of vision to detect potential threats, and if threatened, take flight and seek protection in nearby trees or shrubs. (Balda, 1967, 1975)

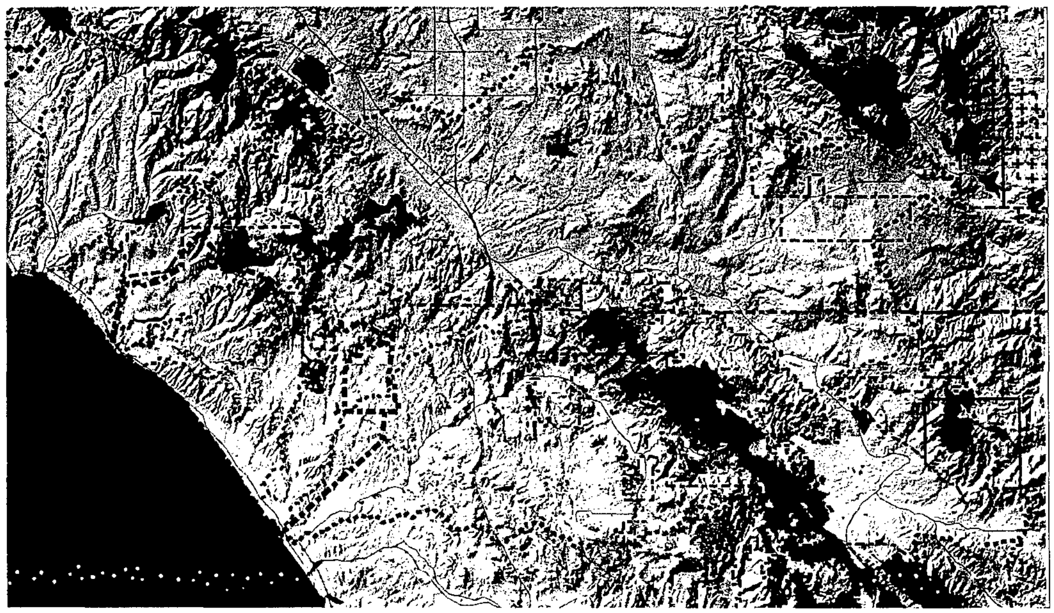
Bluebird habitat could expand by about 85,000ha in **Plans Build-Out**, largely because of the increased openness of new rural residential areas. However, these habitat changes are made less attractive because of the parasitic role of cowbirds in the same areas, and increased fire suppression associated with rural residential development.



Bluebird Potential Habitat: Change

Figure 72

Figure 70



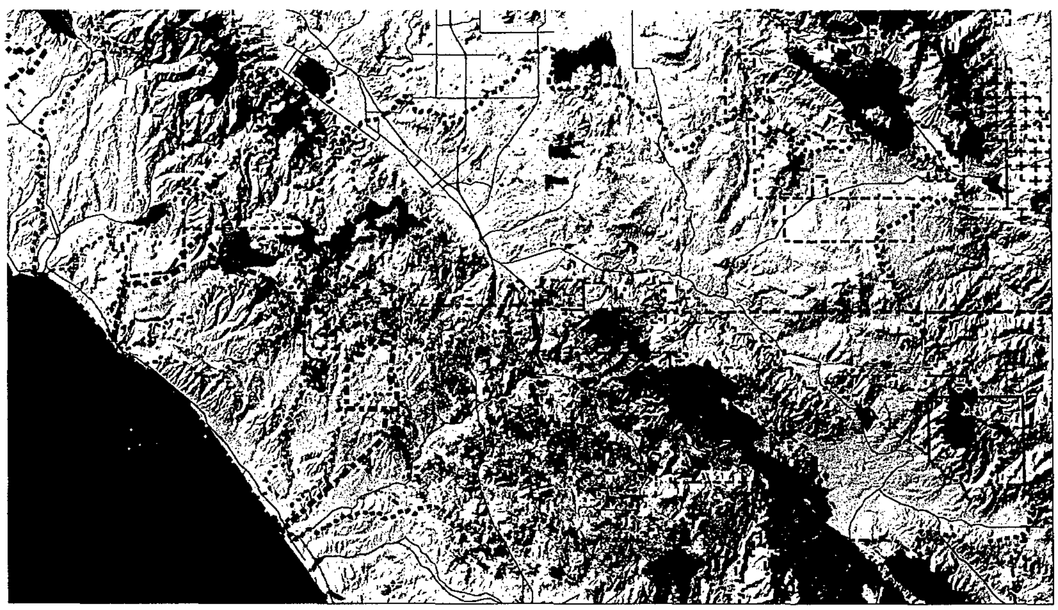
Bluebird Potential Habitat: 1990+

Potential Habitat
280884 ha 8%

Residual
3293163 ha 92%

0 1 3 5 kilometers
0 1 3 5 miles

Figure 71



Bluebird Potential Habitat: Plans Build-Out

Potential Habitat
268106 ha 8%

Residual
3164482 ha 89%

New Habitat
128681 ha 4%

Lost Habitat
12778 ha 0%

0 1 3 5 kilometers
0 1 3 5 miles

Figure 72

The Least Bell's Vireo

The least Bell's vireo, *Vireo bellii pusillus*, is a federally listed endangered species sensitive to changes in riparian vegetation. Preferred habitat for this species is dense willow-dominated riparian habitat with lush understory vegetation (USMC, 1994) that is in high quality 5 - 10 year-old early succession stage (Franzreb, 1989).

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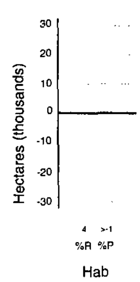

L.B. Vireo Potential Habitat: Change

Figure 66

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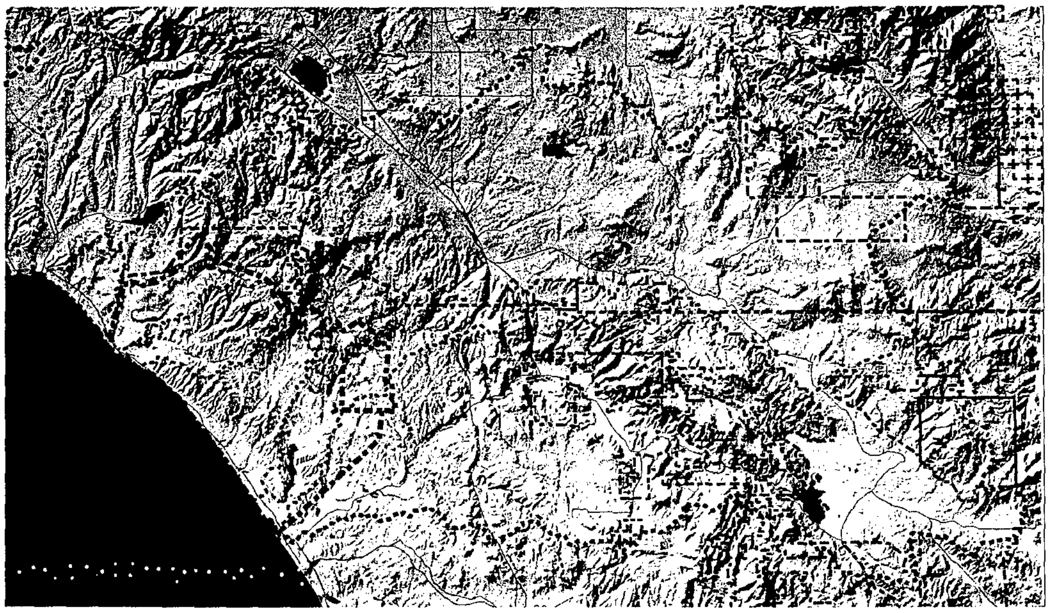
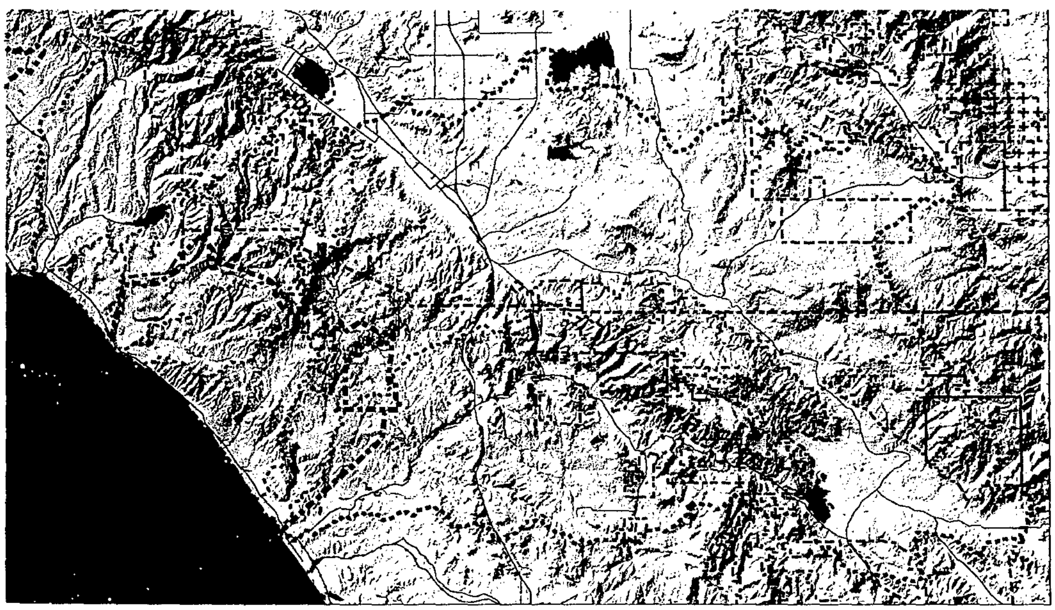
Figure 64



L. B. Vireo Potential Habitat: 1990+

Figure 65



L. B. Vireo Potential Habitat: Plans Build-Out

Figure 66

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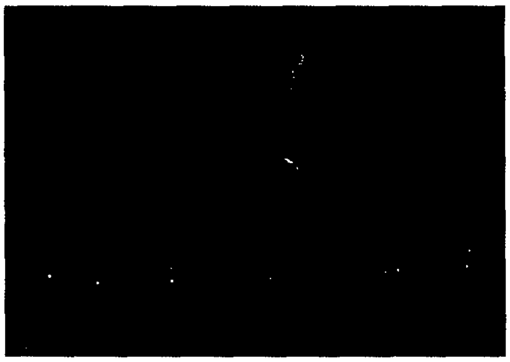
The California Gnatcatcher



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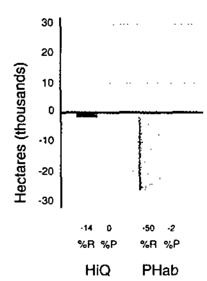

Figure 69

Gnatcatcher Habitat: Change

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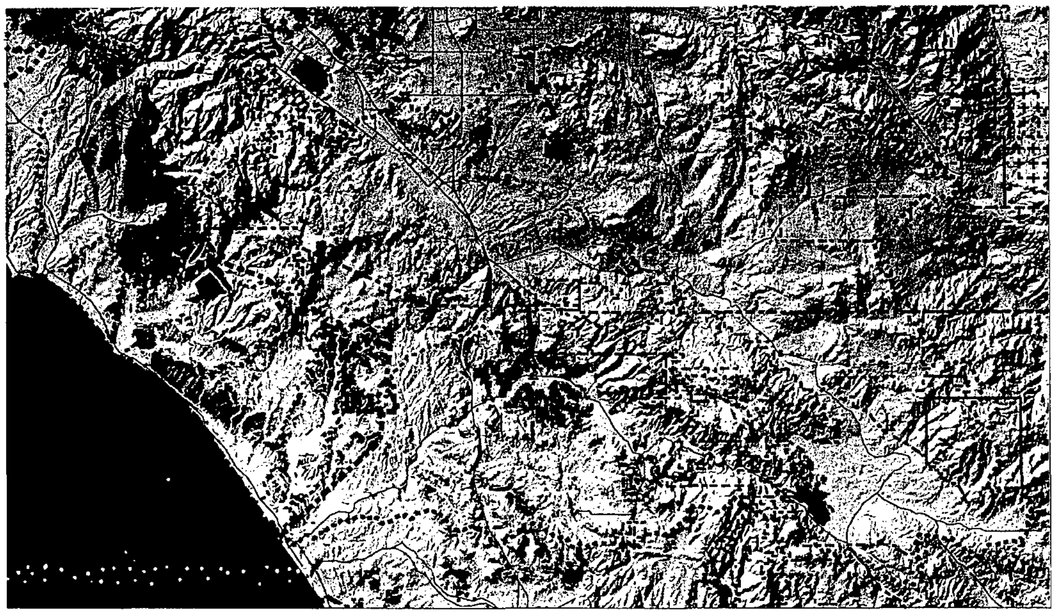
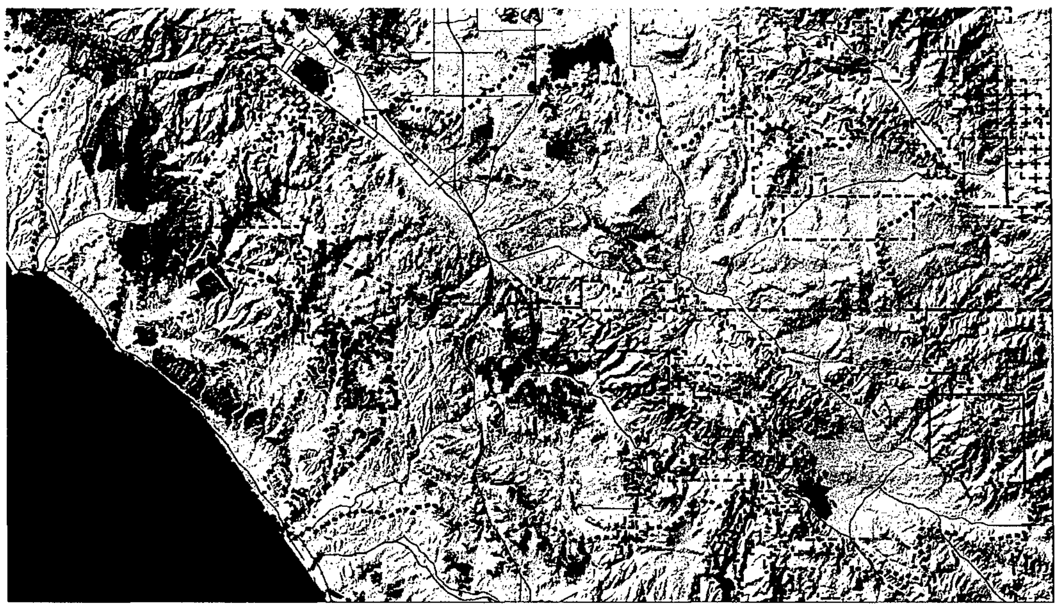
Figure 67



Gnatcatcher Potential Habitat: 1990+

Figure 68



Gnatcatcher Potential Habitat: Plans Build-Out

Figure 69

The Western Bluebird

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The western bluebird is predominately an insectivore. Bent (1949) described the bluebird's diet as 92% animal and 8% vegetable. Typical insects in the diet include grasshoppers, beetles, ants, wasps, flies, and caterpillars. Vegetable items include small fruits such as currants, grapes, elderberries, and mistletoe.

Bluebirds maintain a territory used for mating, nesting, and feeding. Territories tend toward a round or elliptical configuration. Mean territory size for western bluebirds in Arizona is reported as 0.4ha. Bluebirds utilize a keen sense of vision to detect potential threats, and if threatened, take flight and seek protection in nearby trees or shrubs. (Balda, 1967, 1975)

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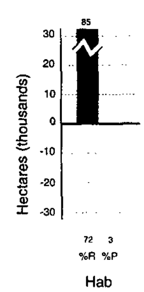

Figure 72

Bluebird Potential Habitat: Change

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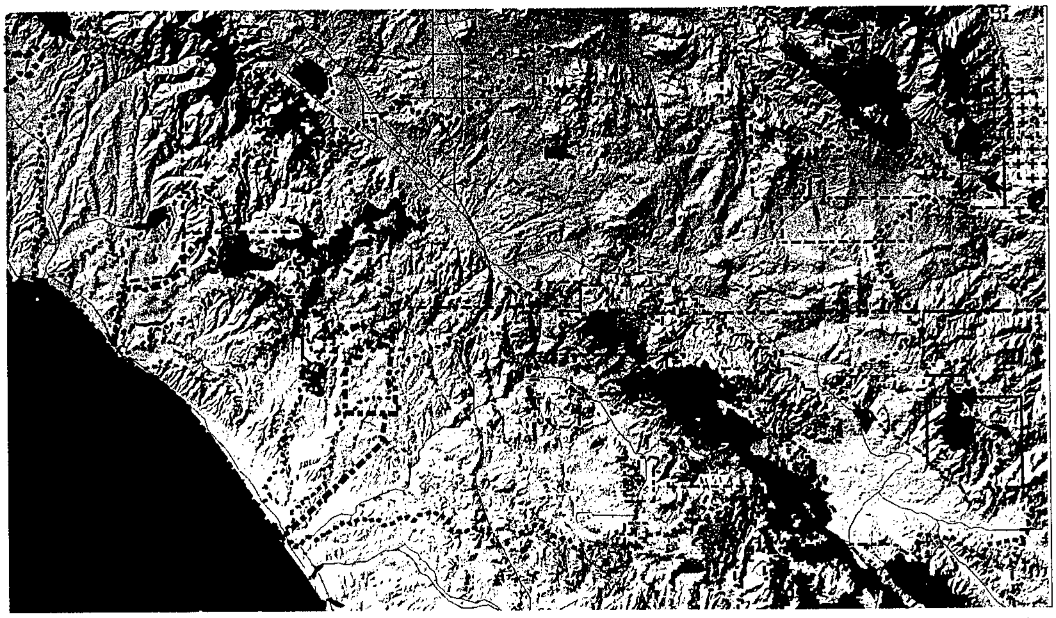
Figure 70



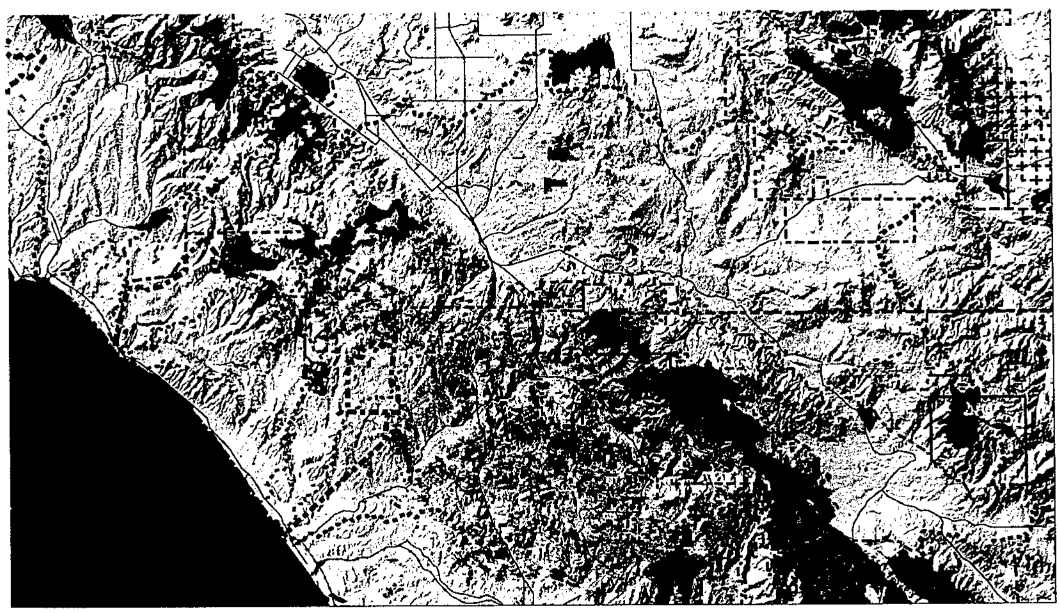
Bluebird Potential Habitat: 1990+

Potential Habitat
280884 ha 8%

Residual
3293163 ha 92%

0 1 3 5 kilometers
0 1 3 5 miles

Figure 71



Bluebird Potential Habitat: Plans Build-Out

Potential Habitat
268106 ha 8%

Residual
3164482 ha 89%

New Habitat
128681 ha 4%

Lost Habitat
12778 ha 0%

0 1 3 5 kilometers
0 1 3 5 miles

Figure 72

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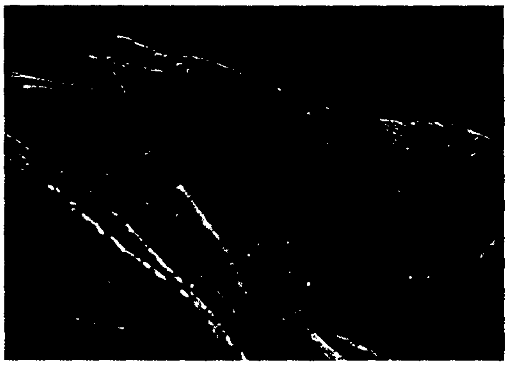
The Brown Headed Cowbird

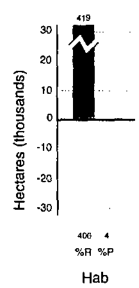


The brown headed cowbird, *Molothrus ater,* is a nest parasitic species which is depressing other passerine bird populations, including the least Bell's vireo. The cowbird has expanded its range from the short grass prairie of the high plains into agricultural and suburban landscapes throughout most of North America. The species has occupied most of California since the 1900s (Rothstein, et al., 1980), where it persists as a year-round resident. The cowbird's preferred habitat is varied and may include prairie, savanna grassland with low or scattered trees, woodland edges, fields, pasture, orchard and residential areas. Cowbirds are, to a certain extent, dependent upon food provided by humans and livestock operations. They are opportunistic generalist feeders, foraging primarily on the ground for seeds, arthropods, and animal waste.

Cowbirds lay their eggs in the nests of other species. While the cowbird's mating strategy may vary depending upon sex ratios in the population (Friedmann, 1929), females begin laying eggs in late April and may continue laying until mid-July. They seem to prefer to parasitize nests in woodland/shrubland edges, often in human-modified landscapes.

The cowbirds home range includes breeding, feeding, and roosting sites. The size of the home range is highly variable. Rothstein (et al., 1984), reported a home range of around 400ha for birds that flew distances of 2 - 7km to feeding areas.

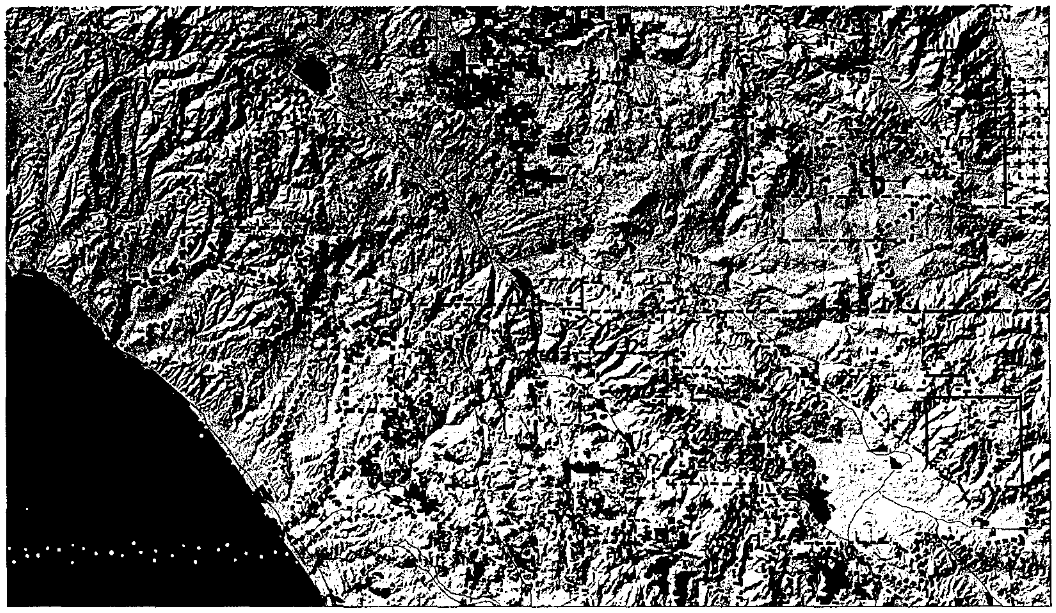
The cowbird population will thrive as a result of **Plans Build-Out**. Habitat could almost quadruple regionally, expanding by about 780,000ha, mainly in new rural residential areas. One important consequence of this expansion will be a decline in bird species parasitized by the cowbird.



Cowbird Potential Habitat: Change

Figure 75

Figure 73

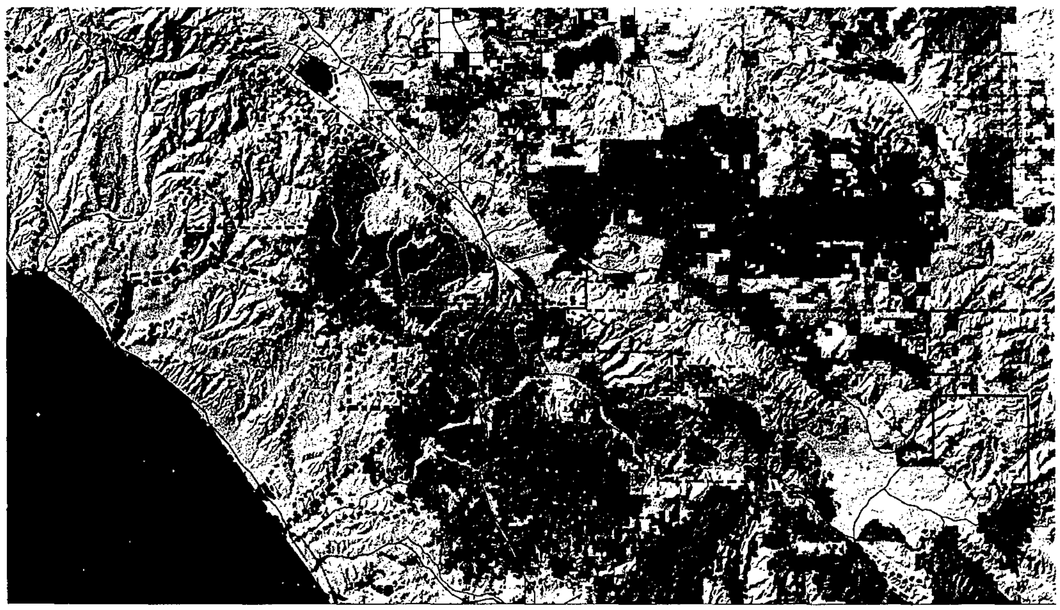


Cowbird Potential Habitat: 1990+

Potential Habitat
237029 ha 7%

Residual
3337018 ha 93%

Figure 74



Cowbird Potential Habitat: Plans Build-Out

Potential Habitat
124495 ha 4%

Residual
2096138 ha 67%

New Habitat
783296 ha 25%

Lost Habitat
112533 ha 4%

The Gray Fox

The California gray fox, *Urocyon cinereoargenteus*, is a mid-level carnivore sensitive to changes in land use intensity. The gray fox prefers woody, bushy, and rocky habitats adjacent to riparian woodlands. The species avoids fields and housing subdivisions with residential densities greater than 1 house per 2ha.

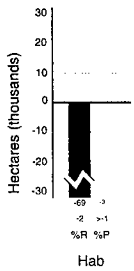
The gray fox is an omnivore whose foods include fruits, grains, small mammals, insects, foods offered by humans, garbage, birds, and carrion (Fritzell, 1987, Harrison, 1995). Small mammals were reported by Grinnell (et al., 1984) to be the most important food source.

Fritzell (1987) noted gray fox preferences for wooded, brushy, and rocky habitats particularly for daytime resting sites. Gray foxes are most active from sunset to sunrise; thus they utilize darkness as a functional type of cover. They are shy and elusive and flee when threatened, often climbing trees to escape. They may also seek cover in dens when threatened. Preferred denning sites include natural caves, rock outcroppings, hollow logs, brush piles, and burrows of other animals that can be enlarged. An average home range for gray fox range of approximately 100ha was reported by Trapp (1978).

Fox habitat will decline by about half, or 65,000ha, as

Fox habitat will decline by about half, or 65,000ha, as a result of **Plans Build-Out**. This is mainly due to new rural residential development in coastal foothills landscapes. Perhaps more significant, the remaining potential habitat pattern will be much more highly fragmented, thus constraining regional movement and genetic transference.

Figure 78



Fox Potential Habitat: Change

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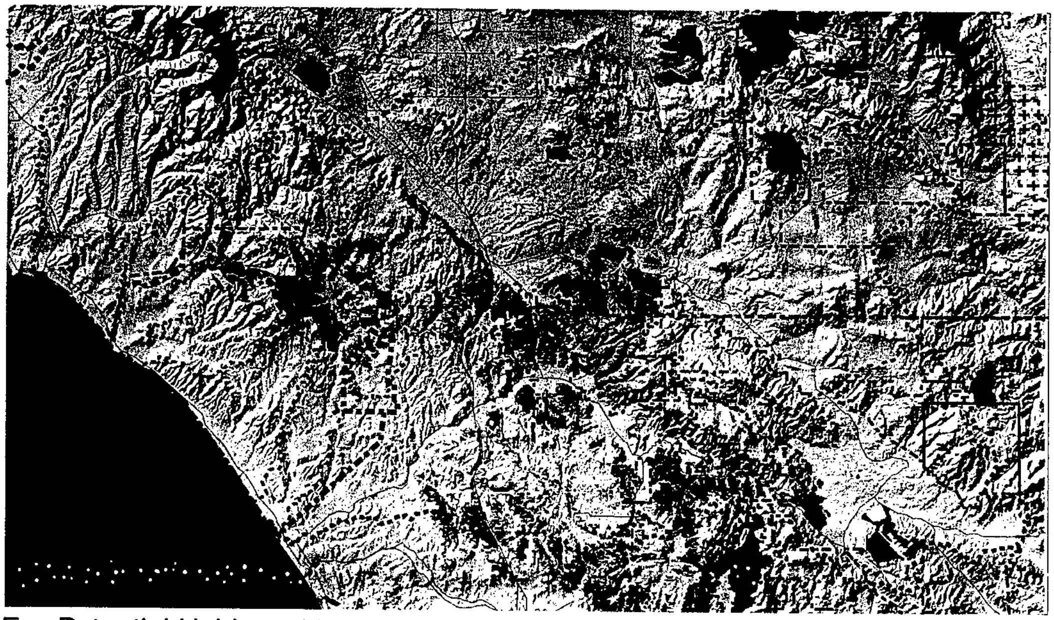
Figure 78

Figure 76



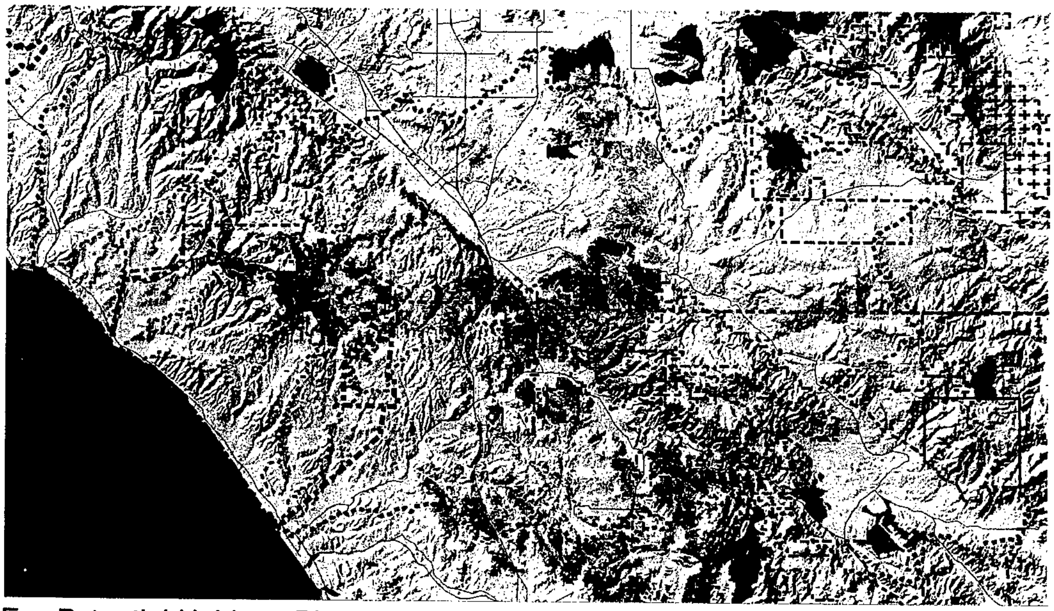
Fox Potential Habitat: 1990+

Potential Habitat
276903 ha 8%

Residual
3297144 ha 92%

0 1 3 5 kilometers
0 1 3 5 miles

Figure 77



Fox Potential Habitat: Plans Build-Out

Potential Habitat
152620 ha 4%

Residual
3296887 ha 92%

New Habitat
257 ha 0%

Lost Habitat
124283 ha 3%

0 1 3 5 kilometers
0 1 3 5 miles

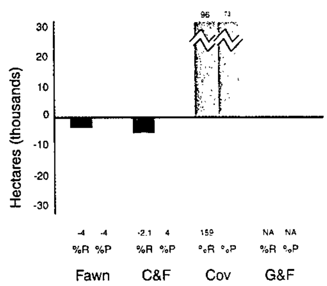
The mule deer, *Odocoileus hemionus californicus*, is the principle food source for the cougar. It is a large ungulate that utilizes and modifies several different plant communities, especially early successional vegetation following fire. The most common home range habitat types for female mule deer are coastal sage scrub, chaparral, and mixed coastal sage scrub. Coastal sage grassland and coastal sage scrub are the most common in male home ranges. Open oak woodlands near water support the highest densities in Camp Pendleton, where mule deer tend to avoid dense chaparral or scrub but will use steep topography if vegetation is not dense. They require dense thickets for escape and thermal cover.

Mule deer feed on a wide range of forage types. Pious (1989) reported a diet of 55% browse, 22% forbs, 10% grasses, 7% nuts, and 8% other materials from rumen samples of Camp Pendleton deer. Interspersed grasslands with abundant forbes are important sites for grazing. Researchers for Environmental Sciences Associates (1992) found the mean distance to water in a mule deer's home range to be around 800m.

Fawning areas contain low shrubs or small trees, forage areas, hiding cover and thermal cover (Thomas, 1979). Home range sizes vary with varying environmental and climatic conditions. The mean home range size reported by Environmental Sciences Associates (1992) was about 1km^2 for females and about 3km^2 for males.

Because of the adaptability of deer to rural residential development, there will be little change in their area of potential habitat as a result of **Plans Build-Out**. The major decline, about 5% of the regional total, will be in the more intensely urbanized parts of the Temecula Valley. Population density within the remaining habitat may decline due to reduced habitat quality and fragmentation.

Figure 81



Mule Deer Potential Habitat: Change

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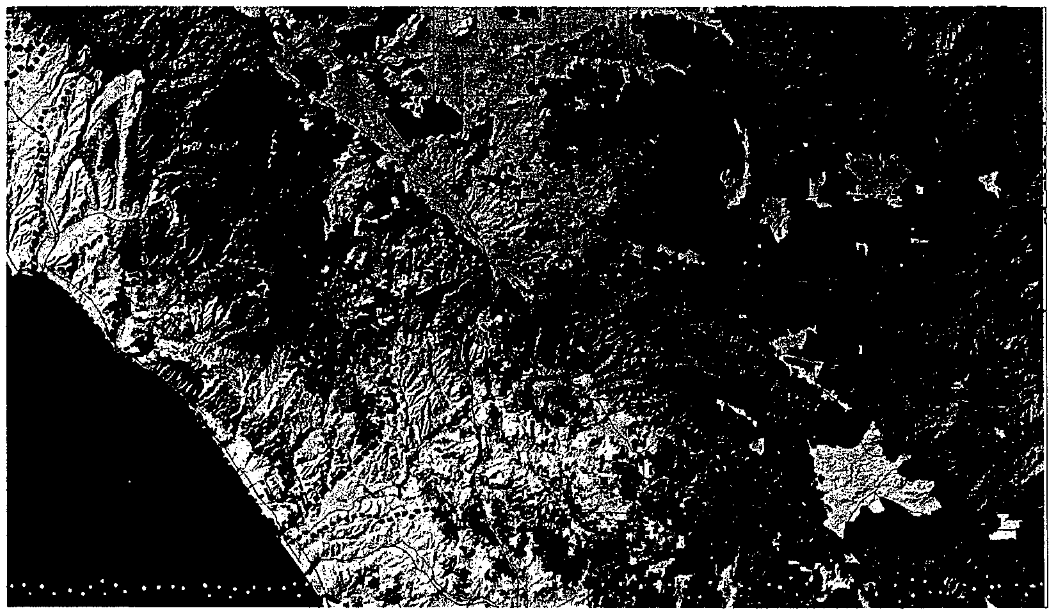
Figure 79



Mule Deer Potential Habitat: 1990+

Fawning
363530 ha 10%

Grassland/ Forage
125838 ha 4%

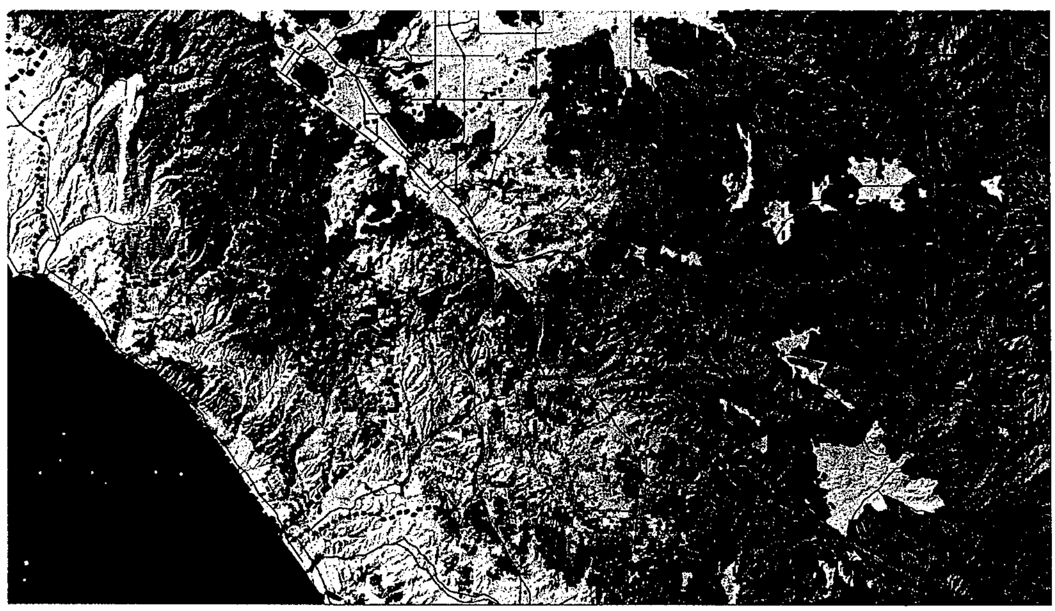
Cover and Forage
1119320 ha 31%

Residual
1578009 ha 44%

Cover
387350 ha 11%

0 1 3 5 kilometers
0 1 3 5 miles

Figure 80



Mule Deer Potential Habitat: Plans Build-Out

Fawning
359351 ha 10%

Grassland Forage
0 ha 0%

Residual
1446280 ha 40%

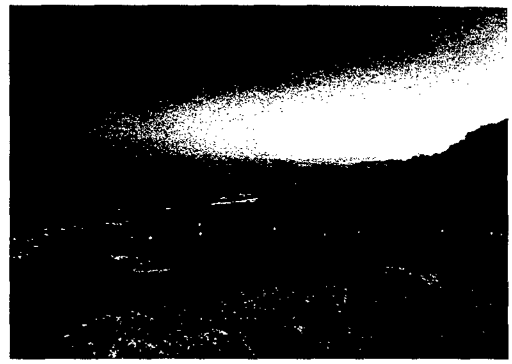
Cover and Forage
1076501 ha 30%

New Habitat
59831 ha 2%

Cover
61444ha 2%

Lost Habitat
193614 ha 5%

0 1 3 5 kilometers
0 1 3 5 miles



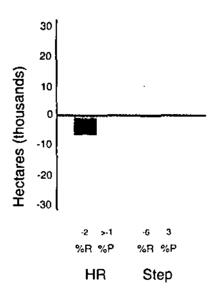
The California cougar, *Felis concolor californicus,* is the top carnivore remaining in the study region. It is an area-sensitive species that requires large contiguous tracts of habitat. Steep canyons, rock outcroppings, boulder fields, and extensive stands of brush and thicket and riparian areas are preferred habitat characteristics. Cougars are opportunistic predators. Their principal food sources in California are large ungulates, black-tailed deer and mule deer in particular. Female cougars with young cannot exist in areas devoid of large prey (Hansen, 1992). One solitary adult cougar will kill one deer every sixteen days on average; a female with cubs, one deer every three days. Transient cougars have a greater reliance on small prey.

Female cougars seek out denning sites within their home range. Russell (1978) identified typical denning sites as caves, space beneath uprooted trees, rocky depressions, or dense thickets.

Home ranges include hunting areas, water resources, resting areas, lookouts, and denning sites. Male home ranges vary from 40 - 800km^2; females from 13 - 650km^2 (Hansen, 1992). For a viable population confined to a single area with no possibility of immigration to persist for 100 years, the minimum patch size must be 1000 - 2220km^2 (Beier, 1995).

The area of cougar habitat will remain relatively unchanged in **Plans Build-Out** because of the existing protection afforded by public lands management and rough terrain. The anticipated decline in mule deer density with **Plans Build-Out** could stress existing cougar populations by reducing the food supply. The cougar however, faces a more serious problem. Interstate-15 has fragmented the regional habitat of the species, making it difficult for cougars in the two existing sub-populations to interbreed. Currently, several cougars die each year on the highway. Male cougars must cross Interstate-15 to sustain genetic diversity within the Santa Ana population; without this, inbreeding will lead to regional extinction in a few generations. A proposal to enable wildlife movement across Interstate-15 will be seen later in this report. This proposal is *not* assumed in **Plans Build-Out**.

Figure 84



Cougar Potential Habitat: Change

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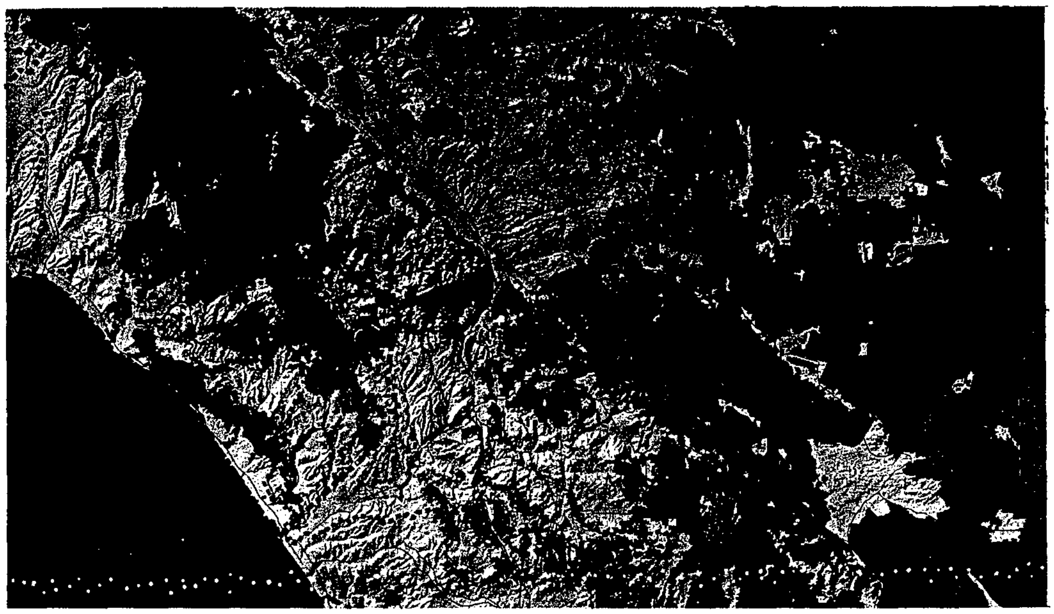
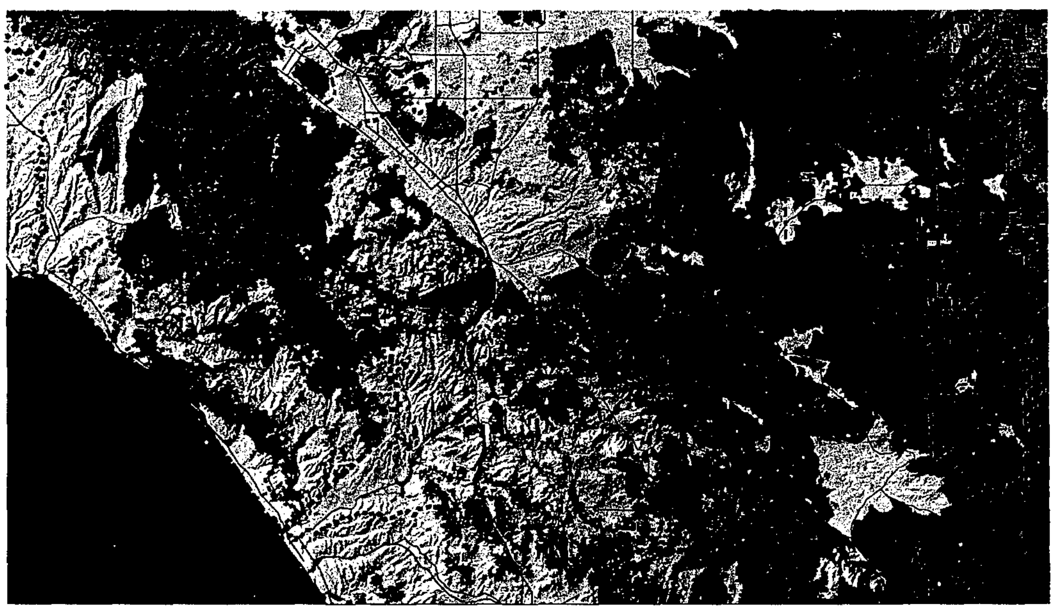
Figure 82



Cougar Potential Habitat: 1990+

Home Range Hab
1815360 ha 51%
Stepping Stones
147286 ha 4%
Residual
1611401 ha 45%

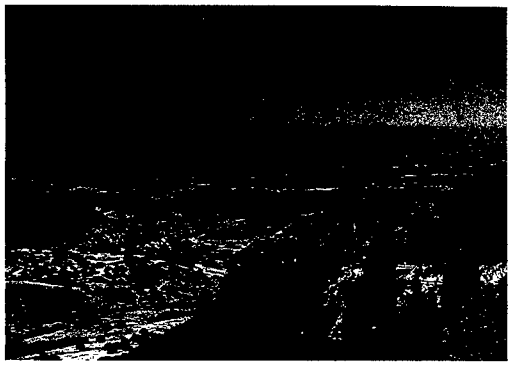
Figure 83



Cougar Potential Habitat: Plans Build-Out

Home Range Hab
1636273 ha 46%
Lost Habitat
181523 ha 5%
Stepping Stones
108354 ha 3%
Residual
1558965 ha 44%
New Habitat
88932 ha 2%

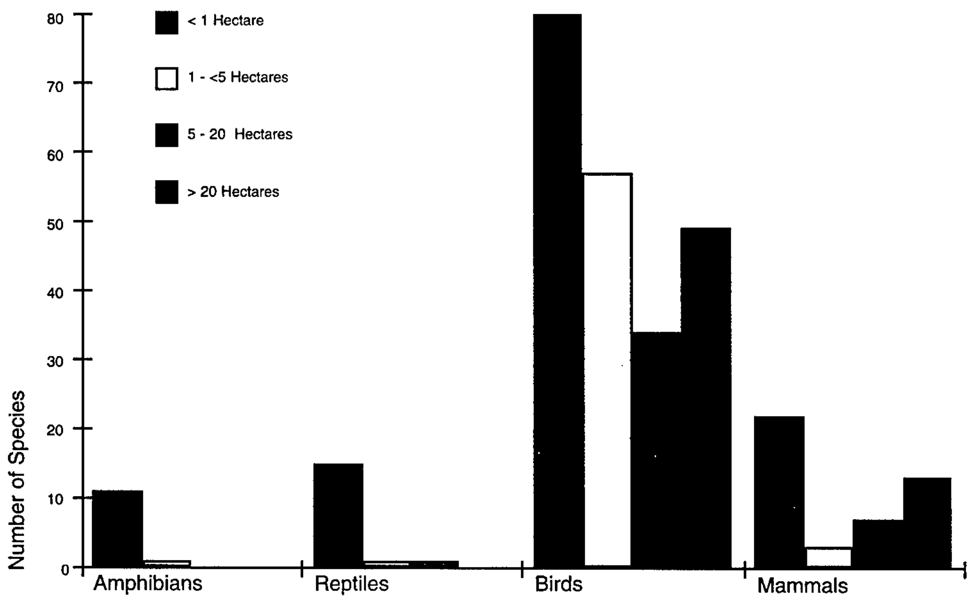
Figure 84



The species richness approach to assessing biodiversity examines the distribution of all resident terrestrial vertebrates: amphibians, reptiles, birds, and mammals. The method is based on the premise that it is possible to use the large sample size of all vertebrate species to provide general patterns of species richness and response to change, even though there is not a great deal of information on each particular species. Although species richness is a simple measure of biological diversity, it provides a basis by which management decisions can be made.

The analysis of species richness involves identifying the vegetation and land cover types in which a given species can be expected to occur. This is called a Wildlife Habitat Relations (WHR) model. In the study region, the Holland vegetation classification scheme describes 375 plant communities, many of which differ only in the ratio of dominant to associated plant species. Ideally, terrestrial vertebrates can be mapped into these classes, thus providing a means for simultaneously assessing plant communities and animal richness. However, information on the

Figure 85



Estimated Home Range Size by Vertebrate Group

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Holland plant communities exceeds the resolution of existing knowledge on species-specific habitat requirements. Further, the Holland communities do not map directly into animal habitats. Mayer (et al., 1988) developed a database relationship between the California WHR models and the Holland classification system. A slightly modified form of this was used for this study.

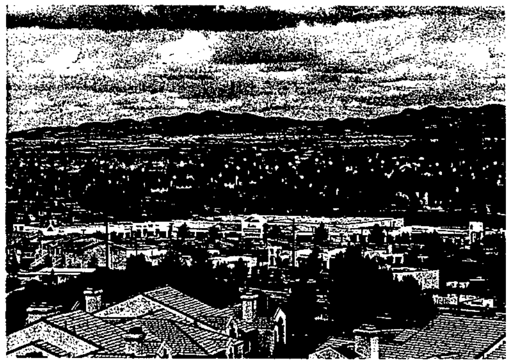
Species-specific WHR models for the study area were obtained from the California WHR models for the southwest valley and mountain province. A tótal of 345 species, including 234 birds, 62 mammals, 36 reptiles, and 13 amphibians, have distributions in the province and were considered to be potentially present in the study area.

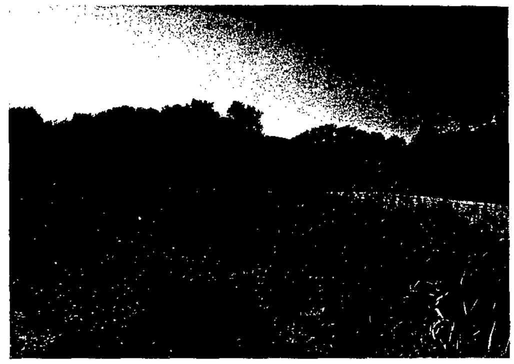
The WHR models were refined for each species by subdividing the "urban" class into three new categories:

Urban: High density housing, commercial, industrial, and transportation land cover.

Single Family Residential: suburban single family housing with one-half to two-thirds of the land area effectively paved and the rest given over to exotic plant species.

Rural Residential: One house per 2ha with approximately 25% of the natural vegetation lost to housing and a surrounding buffer. Since new rural residential development inherits the pre-existing vegetation type, there are many sub-catagories of rural residential development.





Each species was linked to the appropriate Holland vegetation code in the database. Each species WHR was also coded to indicate in which new type of urban development the species might occur. For a species to occur in rural residential it must occur both in rural residential and in the underlying vegetation class.

A spatially explicit depiction of species richness was then developed. This analysis predicted the potential, overlapped distributions of all 345 species in the study area. Figure 86 is the predicted species richness for **1990+**. It is important to remember that this map overestimates actual species richness because it is based on individual species maps of potential habitat, not of known occurrences. This map serves as the base for subsequent analyses estimating the relative change in species richness under different alternative scenarios. The species richness for **Plans Build-Out** is shown in figure 87.

Estimates of required home range size were found in literature for 294 of the 345 species. Generally, the size of the home range is strongly correlated with the body size of that species. Larger animals require more space. Figure 85 shows the distributions of home range size required by the four classes of vertebrates. For each species the number of home range sized patches that occur in the study area was calculated. The analysis then identified those species for which there were fewer than 500 home range patches in the entire study area. Since the analysis was not considering any endemic species, the number 500 was chosen as a compromise of the range values given by Mace and Lande (1991). For **1990+** there were 50 birds and 8 mammals that did not have at least 500 home range patches. Most of the birds are aquatic species such as ducks, reflecting the low level of existing aquatic habitat in the study area. Most of the mammals are large bodied species such as the coyote and bobcat. In **Plans Build-Out** there are 54 birds and 9 mammals without 500 home range patches. This indicates only a slight change in potential species richness.

However, the spatial distribution of species richness declines significantly from **1990+** to **Plans Build-Out**. The statistic of species richness is the number of species predicted to be in a pixel times the number of pixels that have that value. Figure 88 shows the distribution of species richness for **1990+** and **Plans Build-Out**.

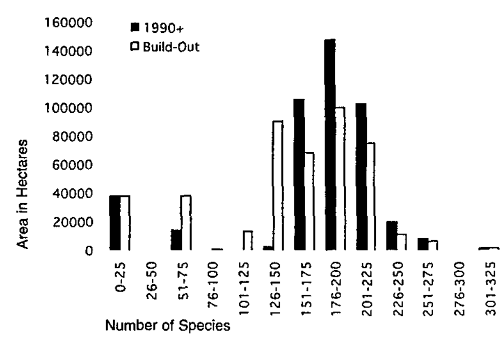


Figure 88

Change in Area of Species Richness

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Figure 88

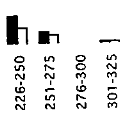

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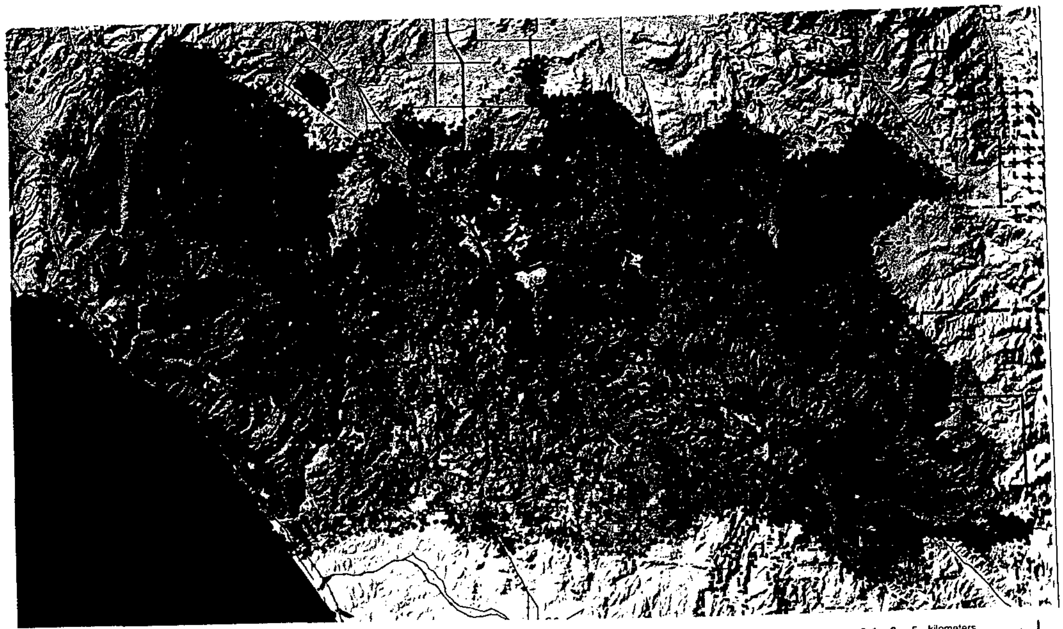
Figure 86



Species Richness: 1990+

0 to 50 Species
124370 ha 8%

51 to 100 Species
48801 ha 3%

101 to 150 Species
11743 ha 1%

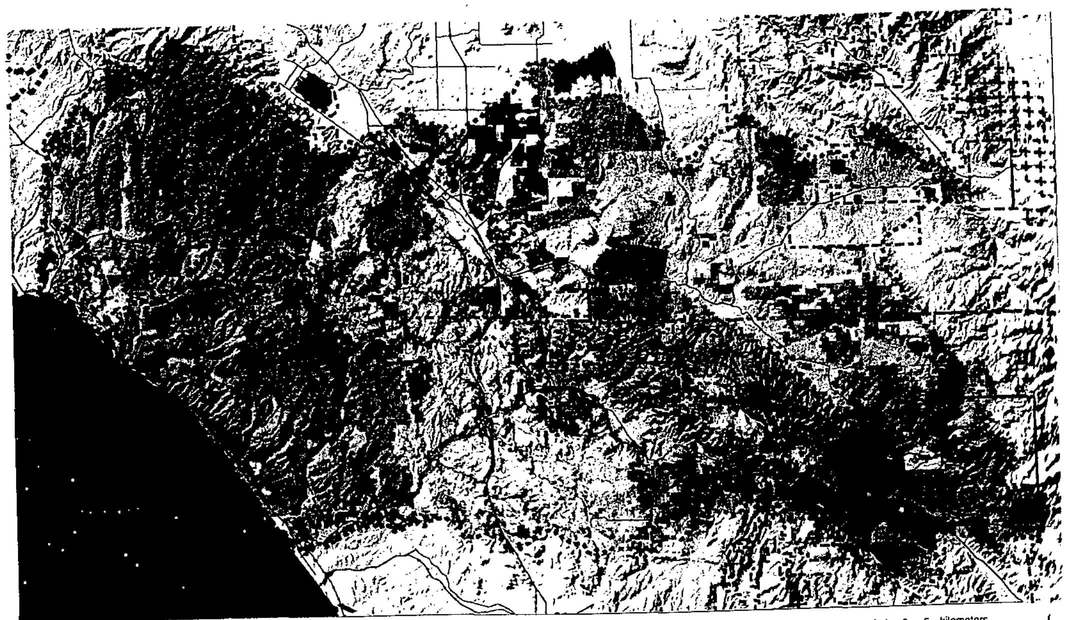
151 to 200 Species
844239 ha 57%

201 to 250 Species
407126 ha 28%

251 to 300 Species
29888 ha 2%

301 to 325 Species
7451 ha 1%

Figure 87



Species Richness: Plans Build-Out

0 to 50 Species
124845 ha 3%

51 to 100 Species
129482 ha 4%

101 to 150 Species
344130 ha 10%

151 to 200 Species
5606902 ha 16 %

201 to 250 Species
287579 ha 8%

251 to 300 Species
22347 ha 1%

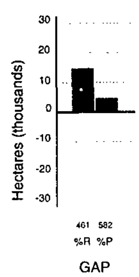
301 to 325 Species
5002 ha 0%

One approach that systematically evaluates the protection afforded species richness in a given area is called GAP Analysis. The method identifies those areas in which individual species and/or groups of species are found and determines if they fall within areas of active management plans for biodiversity (Edwards, et al., 1993). Those areas with active management plans for conserving biodiversity are considered relatively stable environments for species. Those areas with high species richness values but without active management plans focused on maintenance of biodiversity are considered "gaps." Individual species distributions that have no area contained potential habitat within protected and managed zones can also be viewed as gaps.

GAP Analysis consists of three primary investigations: the distribution of actual vegetation cover and land cover (figure 10); the protection and management status of public and private property (figure 11); and distributions of terrestrial vertebrates as predicted from the distribution of cover types and known observations which are reflected in the WHR models. A central assumption of GAP Analysis is that mapped vegetation accurately represents the spatial distribution of terrestrial vertebrates. The GAP Analysis used only those 294 species for which home range data were available. Patches of habitat which were too small to support the home range of a given species were dropped from the map of that species. This filtering reduces the overestimate of the richness maps, but does not eliminate it.

The spatial extent of gaps in protection and their associated species, are identified by intersecting the species richness map with the map of protected areas. The GAPs in species richness for **1990+** are shown in figure 89. For the current plans of the region the estimate of risk was determined by intersecting **Plans Build-Out** with gaps outside the current protected areas and the plan's proposed conservation areas. Those areas that contained individual species distributions not contained within an active management plan zone were identified as gaps. The zones at risk represent a logical focus-areas for future conservation efforts in the study area, and are shown in figure 90. If some of these zones are not afforded active management plans for conservation, regional species extinction is a possibility.

There is 2.6 % increase in GAP pixels from **1990+** to **Plans Build-Out**, representing about 11,700ha of additional land that is identified as important for conservation. Figure 91 shows this change. The values are the number of GAP pixels weighted by the number of unprotected species in each pixel. The species which are not protected in this analysis are all water birds. It is important to remember that the definition of protectedness used here is weak: a species has only to occur in a protected area. Stronger criteria such as considering minimum habitat size in a protected area or redundancy among separated areas would show more species as being at risk.



GAP Analysis: Change

Figure 91

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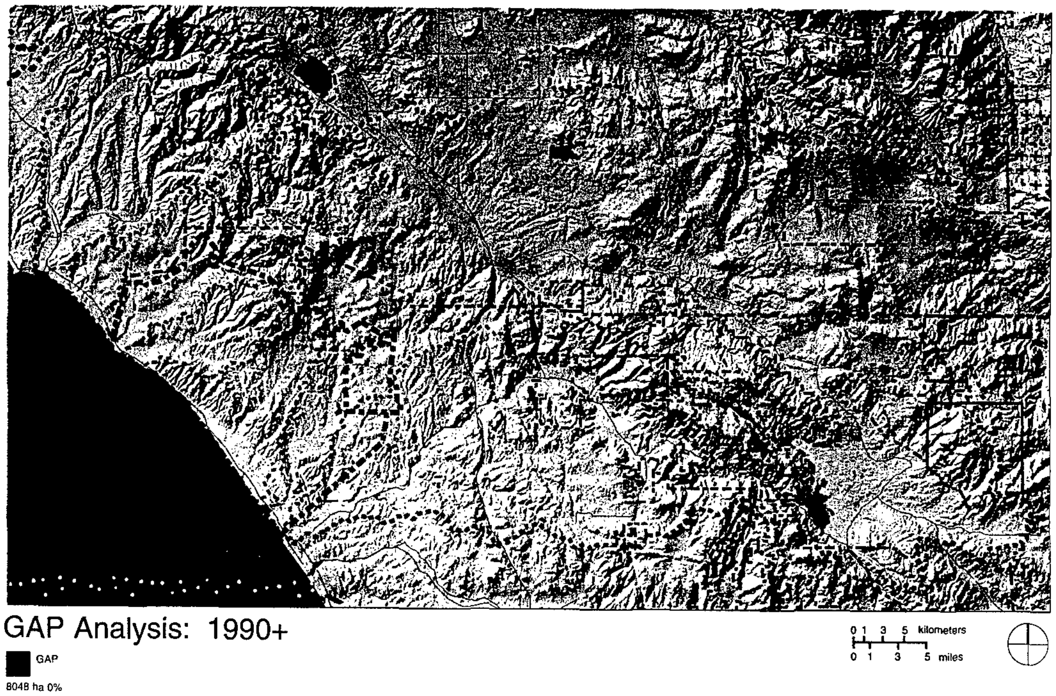
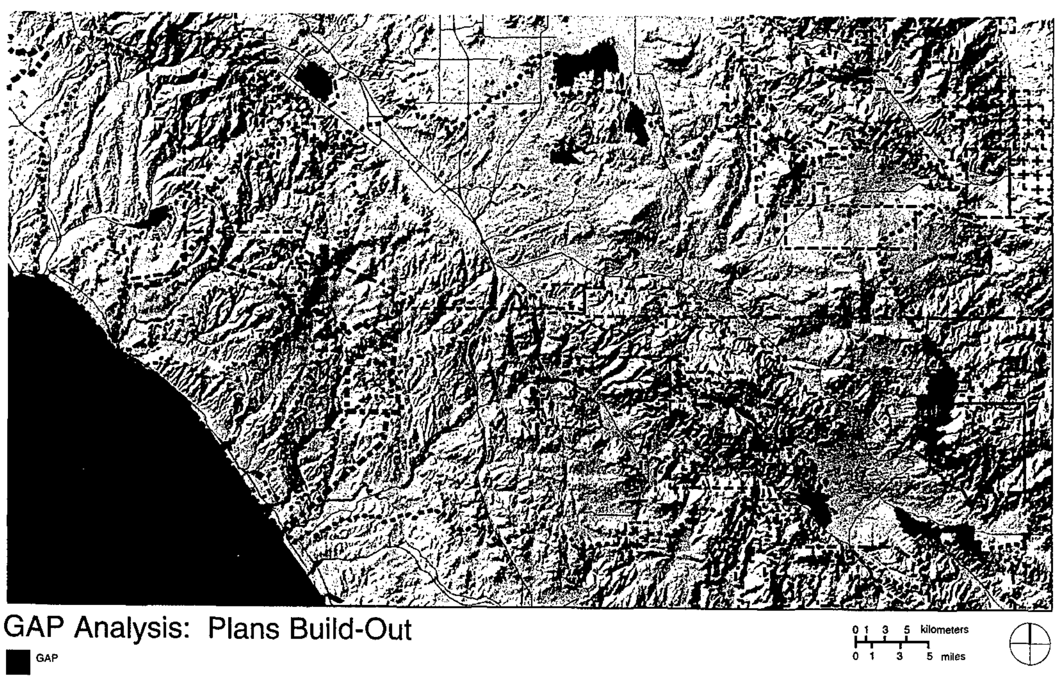
Figure 89



GAP Analysis: 1990+

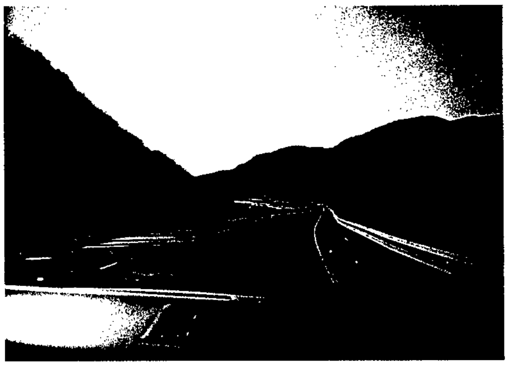
Figure 90



GAP Analysis: Plans Build-Out

Figure 91

Visual Preference



Humans, as another component of biodiversity, understand their environment primarily through what they see, and in southern California what they see is primarily viewed from automobiles. This study therefore includes a model of the impact of future change on visual preferences. The visual model follows the organizational strategy of the methods used by the USDA Forest Service (1974) and the Bureau of Land Management (1980). There are three phases: 1) preferences; 2) exposure; and 3) value.

The first step is a survey of visual preferences. While such an evaluation is subjective, it provides insight into commonly held perceptions and values regarding the visual qualities of the landscape. To determine whether or not personal experience altered visual preferences, two experiments were conducted: a "geographic study" and a "training study" (Bales and Blomberg, 1996). In the geographic study, eighteen persons from California and sixteen from New England were interviewed to test if Californians, whose experience, perceptions, and values of the landscape were formed in the study area, had significantly different preferences than those from outside the region. In the training study eleven Harvard Graduate School of Design students and twenty-three non-students were interviewed in order to test the difference in preferences of people who have been trained to be perceptive of their visual environments and those who have not.

Preferences were determined by using a set of 26 photographs of the study area which represent the range of land cover types in the region.

Figure 92

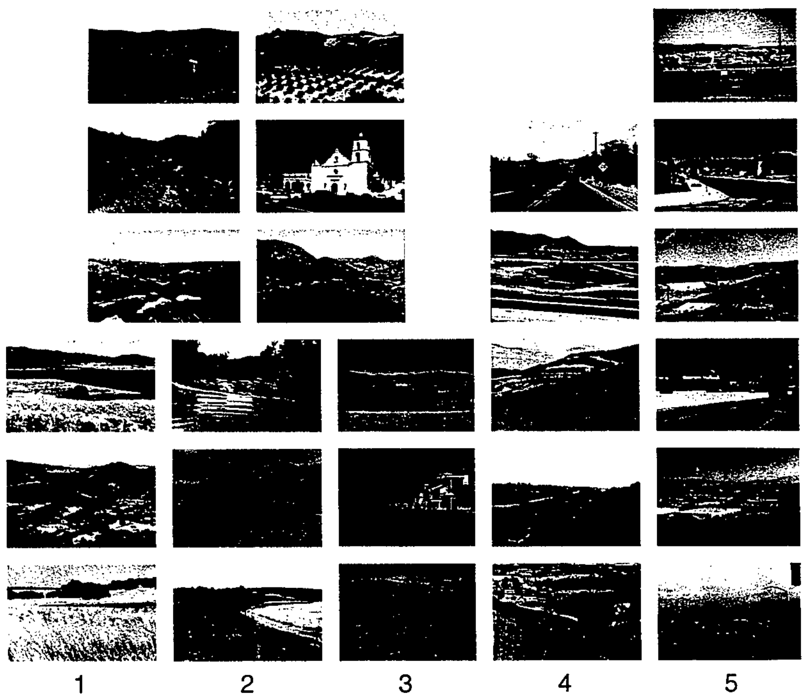


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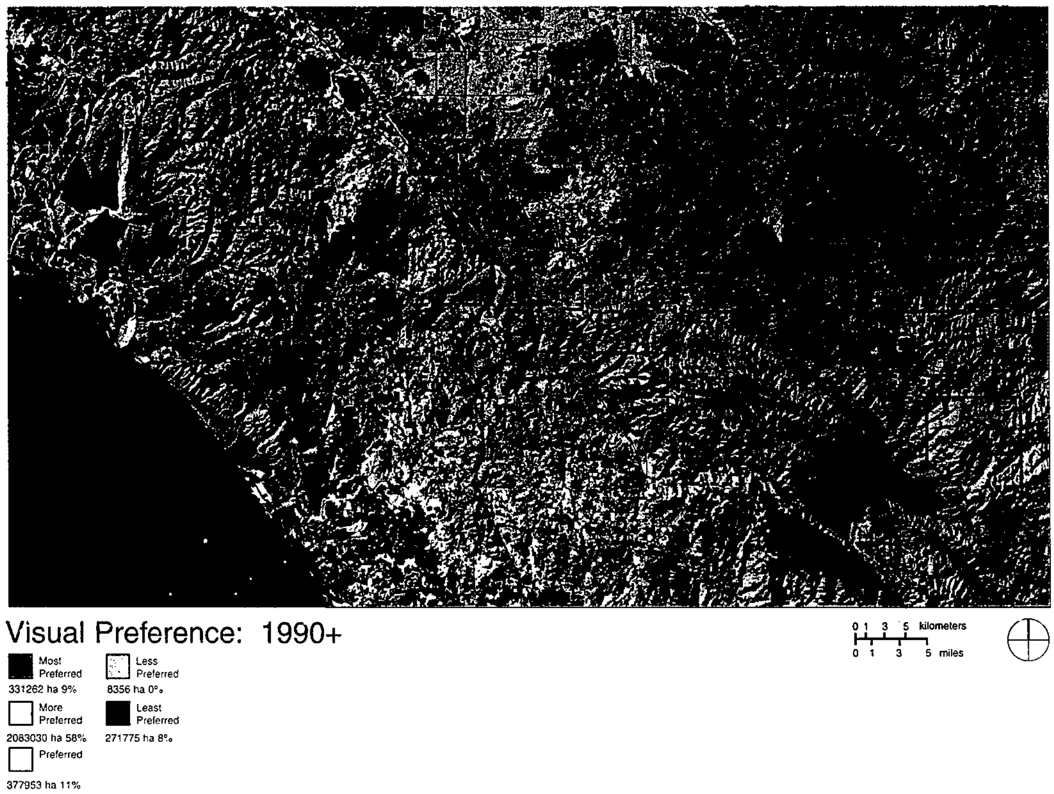
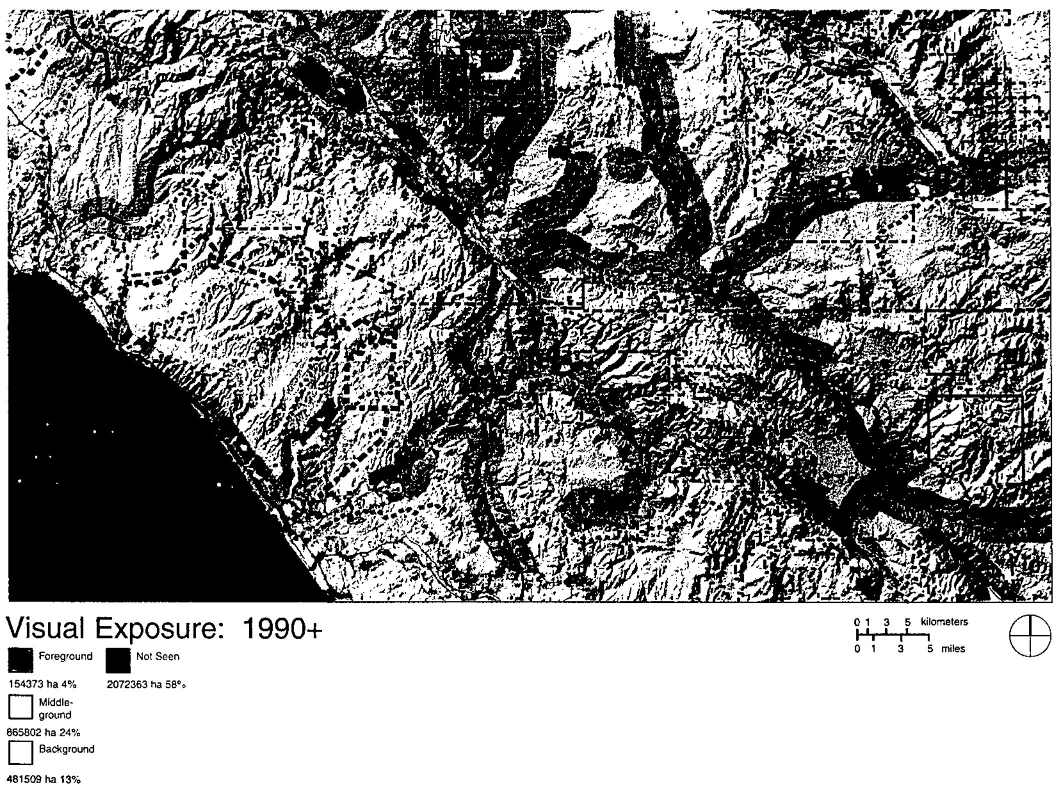
Figure 93



Visual Preference: 1990+

Figure 94



Visual Exposure: 1990+

Participants were asked to arrange the 13cm by 18cm color photographs into five numbered piles ranging from 1 (Most Preferred) to 5 (Least Preferred). There was no required maximum or minimum number of photographs in each pile. The participants were given as much time as they felt necessary for the task. They were permitted to change the location of any photograph until they were satisfied with its location.

Average values were then charted by sub-sample and also in the aggregate. The results of the study showed that there were no significant variations in the landscape preferences of the different groups. Significant variations were defined as a change of more than one set on the chart. Figure 92 shows the twenty-six photographs grouped by aggregate average value range, from "Most Preferred" to "Least Preferred."

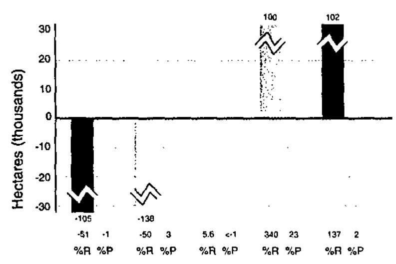
The survey photo characteristics were then described in GIS land cover categories. A map of the **1990+** pattern of visual preference is shown in figure 93. This pattern will change considerably as a result of **Plans Build-Out**.

Exposure was defined in terms of whether areas were visible in the foreground, middleground, or background, or not visible, from all the major transportation routes in the study areas. The Exposure Pattern for **1990+** is shown in figure 94.

Preference and exposure were combined to define the value of preferred landscapes. For example, areas that were in the most-preferred class and were also the most exposed were assumed the most valuable to protect. At the opposite extreme, areas which were least preferred and least exposed are where maximum change might take place. If the study region's many jurisdictions would adopt policies that would manage the region's most valuable visual qualities (and **Plans Build-Out** does *not* assume this) then the locations which might adopt the five policy levels of preservation, retention, partial retention, modification, and maximum modification in **1990+** are shown in figure 95.

Because of the absence of such policies, there will be significant impacts on many of the region's most visually preferred and exposed landscapes caused by **Plans Build-Out**. These are shown in figure 96.

One consequence of this projected pattern of visual change is that highly scenic roads will become quite rare in the region. One such scenic road is the Ortega Highway, Route-74, which runs east-west through the Cleveland National Forest. Because of increased traffic demand generated by urban growth in the Temecula Valley, there will be pressure to expand capacity. Some proposals with this aim have already been made. While there may be traffic benefits derived from widening this road or building new roads, the visual consequences are likely to be negative. More importantly, the region's single largest contiguous habitat zone would be split by a wider expanse of concrete and macadam. This would be a threatening circumstance for biodiversity.



Visual Value: Change

Figure 97

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Figure 97

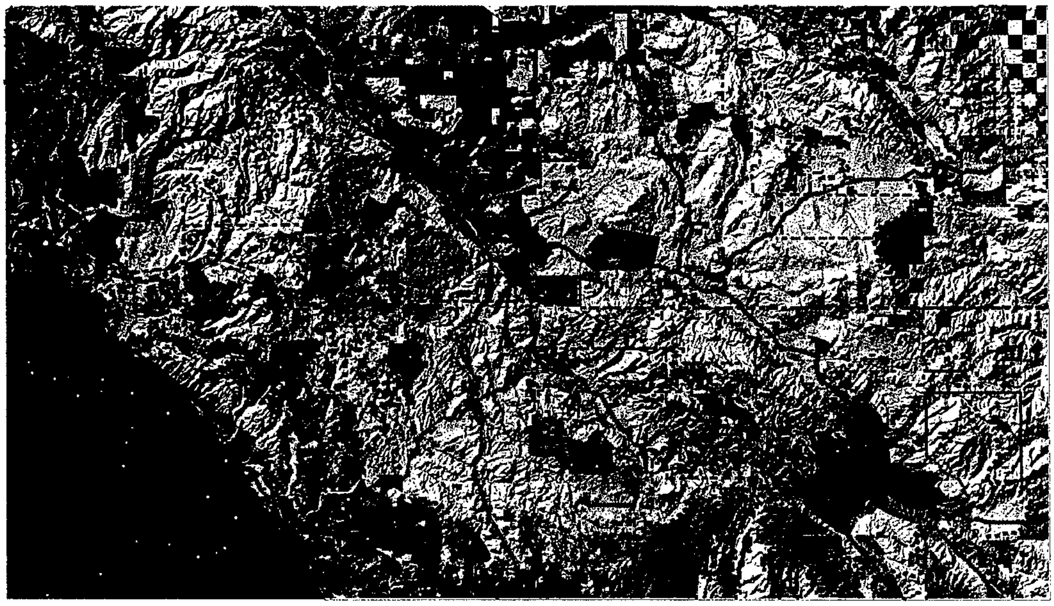
Figure 95

Visual Value: 1990+

Preservation — 401039 ha 11%
Modification — 87337 ha 2%
Retention — 562549 ha 16%
Maximum Modification — 277957 ha 8%
Partial Retention — 1753496 ha 49%

0 1 3 5 kilometers
0 1 3 5 miles

Figure 96



Visual Value: Plans Build-Out

Preservation — 216897 ha 6%
Modification — 394809 ha 11%
Retention — 326575 ha 9%
Maximum Modification — 593517 ha 17%
Partial Retention — 1539366 ha 43%

0 1 3 5 kilometers
0 1 3 5 miles

As can be seen in the previous sections, almost all measures of environmental change, including the several assessments linked to biodiversity, decline dramatically between **1990+** and **Plans Build-Out**. This is not a surprise. But, seen from a human perspective, this is not an overall disaster. Southern California may still be a relatively attractive place to live, albeit a biologically poorer region.

The next question is, can we do better than the current plans and their build-out for both humans and other species? Are there alternatives that should be considered that can accommodate the forecasted population growth and also maintain the region's high biodiversity and other environmental qualities? And at what scale should such alternatives be considered?

Four investigations toward this end were undertaken as part of this study, and are located in figure 98.

The first and smallest is the proposed restoration for riparian habitat of three abandoned sewage treatment ponds on MCB Camp Pendleton.

The second is an analysis of an existing subdivision on the Santa Rosa Plateau, and a proposal to enable wildlife to move more easily through the landscape when houses are built and occupied.

The third is the comparison of alternative development-guideline strategies for an undeveloped third order watershed, "Oak Grove."

The fourth is the comparison of alternative futures for the entire region based on different strategies directed at accommodating development and maintaining high biodiversity.

Figure 98

Four Scales of Change: 1990+

Water	Mixed Forest 147617 ha 4% ha	Grasslands 168775 ha 5%	Single Family Res 79521 ha 2%	Military Impact 50221 ha 1%
Riparian Vegetation 21051 ha 1%	Orchards 79808 ha 2%	Altered Land 161655 ha 5%	Multi Family Residential 90344 ha 3%	Commercial Industrial 86848 ha 2%
Oak Woodland 131095 ha 4%	Sage, Chaparral 1640626 ha 46%	Rural Residential 276226% 8%	Military Maneuvers 117124 ha 3%	Trans-portation 14105 ha 0%

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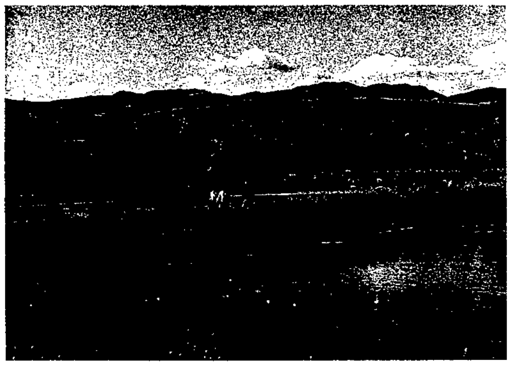

The hydrological regime of the Santa Margarita River is typical of most major rivers in southern California. It has been altered by development in the watershed, water diversions, channelization, substantial withdrawals from the aquifer, and the invasion of exotic plants. The alterations have modified and stressed both plant and animal communities, especially those linked to riparian habitat. Findings noted in the Programmatic Groundwater/Riparian Habitat Assessment at MCB Camp Pendleton, California (1995) suggest that the Percolation Ponds at Ysidora Basin and at Sewage Treatment Plant 3 (STP3) contribute substantially to ground water recharge during the dry season, but could adversely impact riparian vegetation during extended periods of drought.

This study investigated the potential for the restoration of the Ysidora Basin, STP3, and Sewage Treatment Plant 8 (STP8) Percolation Ponds into habitats compatible with those of the immediately adjacent landscape. Since all three restoration sites are in, or immediately adjacent to, riparian scrub plant communitites, restoration plans will be oriented toward riparian scrub for STP3 and the Ysidora Percolation Ponds, and coastal sage scrub (CSS) grassland for STP8. The goal of the restoration plans is to create self-sustaining and functioning riparian or CSS ecosystems which are capable of long-term regeneration following natural disturbances and which will support a complete assemblage of avian species including least Bell's vireo.

Restoration of riparian scrub habitat in southern California is a relatively new endeavor. Consequently, restoration of that habitat type is as much an art as a science. Overall success rates for wetland/riparian habitat restoration in arid environments is relatively low, and primary obstacles to be overcome include (Baird, 1989):

> Selecting or creating planting sites that are similar to those supporting existing riparian vegetation. In Southern California these areas have an average water table depth between three and four feet from ground surface, a sandy or gravelly soil type, and are periodically flooded.
>
> Establishing cuttings, tubings, potted planted material or natural seed.
>
> Maintaining or introducing soil flora, particularly mycorrhizal fungi.
>
> Controlling weed competition.

Literature on riparian scrub and CSS function, structure, and restoration specific to southern California was reviewed. The life histories and horticultural requirements of dominant riparian species common to MCB Camp Pendleton were researched, and base biologists Boyers and Griffiths (1995) were consulted on the success of previous on-base riparian habitat restoration efforts. Alternative conceptual plans for each site were prepared and reviewed on site with Camp Pendleton biologists, and final proposed plans incorporated all recommended revisions.

At the present time, as shown in figure 99, the Ysidora Basin Percolation Ponds are heavily vegetated with willow, *Salix spp.*, cottonwood, *Populus fremonti*, emergent aquatic species, and some exotics including giant reed and salt cedar. These plants became established after the levees were breached in the 1993 flood. The levees are either barren or support grasses and forbs, and often weed species. Dense riparian scrub surrounds the exterior levees. The area is heavily utilized by least Bell's vireos and other riparian habitat dependent avian species.

The design for the restoration of the Ysidora Basin Percolation Ponds, figure 100, is to allow the Santa Margarita River to flood the pond basins by removing all existing levees. Without periodic flooding the existing vegetation in the Percolation Ponds would succeed into an old, even aged stand of limited species diversity. Habitats with these characteristics are of little value to least Bell's vireos, the target species for this restoration project. The restoration of the historic flooding pattern would permit periodic scouring of segments of the basins, exposing sites suitable for pioneering riparian plant establishment. A self-sustaining, transient pattern of differentiated age stands of willow, cottonweed, sycamore, *Platanus racemosa*, mulefat, *Roaccharis glutinosa,* and herbaceous species should result. The structural diversity and temporal variability of this pattern should meet the criteria described in the least Bell's vireo habitat model and should also be sufficiently diverse to support a variety of other avian species.

This design assumes an aggressive giant reed and salt cedar control program. An ongoing effort is necessary to keep these and other weed species from outcompeting native riparian species on sites exposed by flood events.

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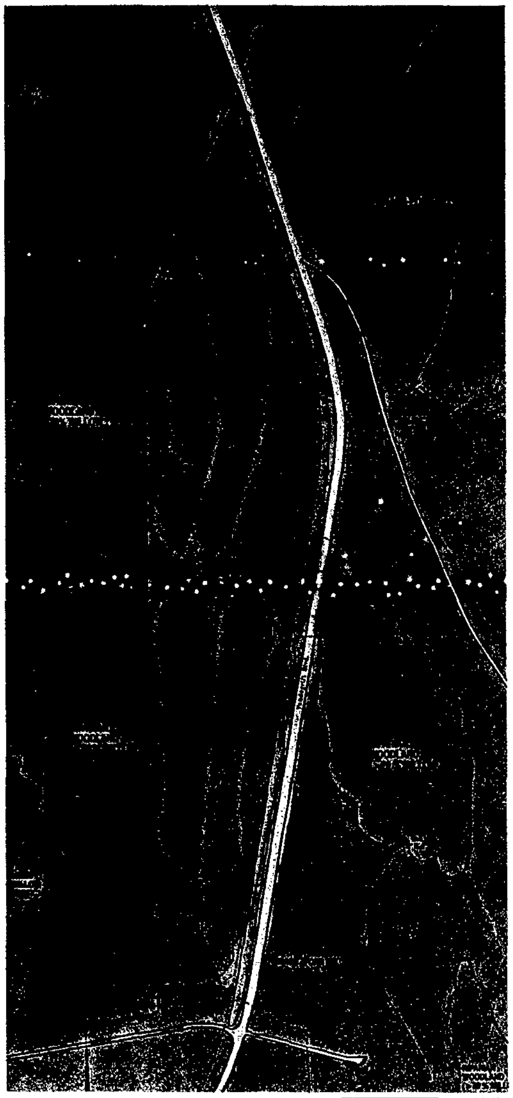

Figure 99 Existing

0 200 400 600
Scale (In Feet)
1" = 200'

LEGEND

- Contour Line
- River or Creek
- Railroad
- Unpaved Road
- Existing Heavy Brush or Wooded Area
- Least Bell's Vireo (status undetermined)
- Least Bell's Vireo Nesting Pair
- Least Bell's Vireo (Territorial Male)
- Soil Type Boundary

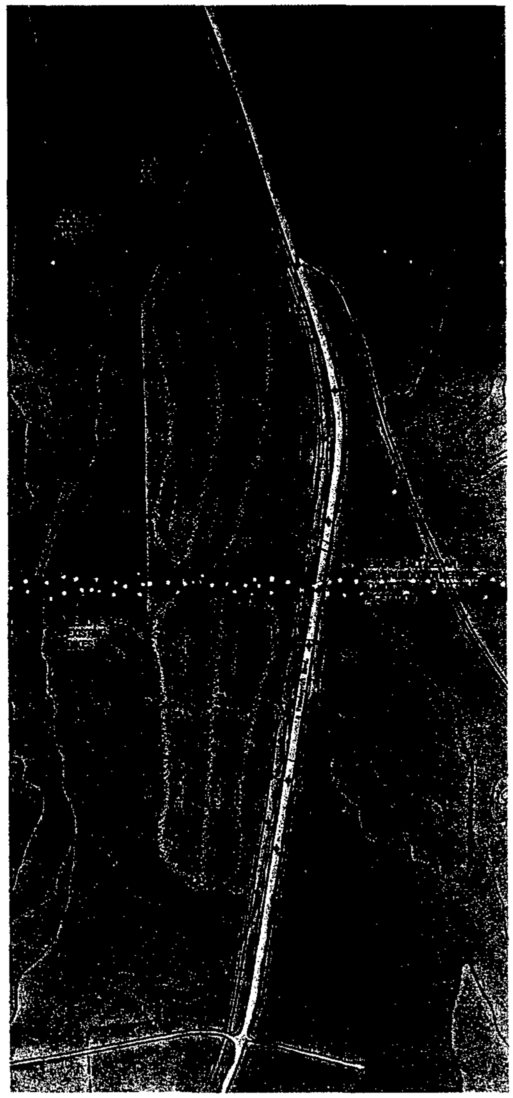

Figure 100 Proposed

0 200 400 600
Scale (In Feet)
1" = 200'

LEGEND

- Contour Line
- River or Creek
- Railroad
- Unpaved Road
- Existing Heavy Brush or Wooded Area

Percolation Ponds at STP3

At the present time, as seen in figure 101, the three STP3 ponds are filled with water. A collar of emergent aquatic vegetation rings the inside perimeter of each, and dense stands of riparian scrub exist along the exterior of the south and west levees. Use of these areas by the least Bell's vireo has been documented, and waterfowl utilize the ponds.

The design, shown in figure 102, assumes that the proposed airfield levee will be constructed north of the existing STP3 ponds, but that the ponds would not be protected by it. The design recommends that all existing interior pond levees be removed. In addition, it is recommended that the pond basins be lowered an estimated 1m to an elevation of 11m, within 0.2m of the high water table. This elevation would place newly planted trees and shrubs within 2m of the mean water table elevation of 10m. This is a requisite for long-term plant survival. An irregular base grade is proposed to create a variety of micro-habitats to support a diversity of plant species. Leaf litter and debris from adjacent riparian plant communities would be spread over the graded base to re-introduce mycorrhizal fungi, which are important in stimulating the growth of new plantings on restored sites. The regraded and prepared basin would be revegetated using species, spacing, and densities appropriate as least Bell's vireo habitat. The outer levees would be removed three to five years later, after the planting established. This sequence of levee removal would protect the new plantings through establishment and ultimately allow the river to flood freely into the former pond basins.

Once established, the specified plant species are pre-adapted to survive the flood and potential burial by silt and sand. This design will allow the plant community and ponds to become a functional part of the Santa Margarita River floodplain.

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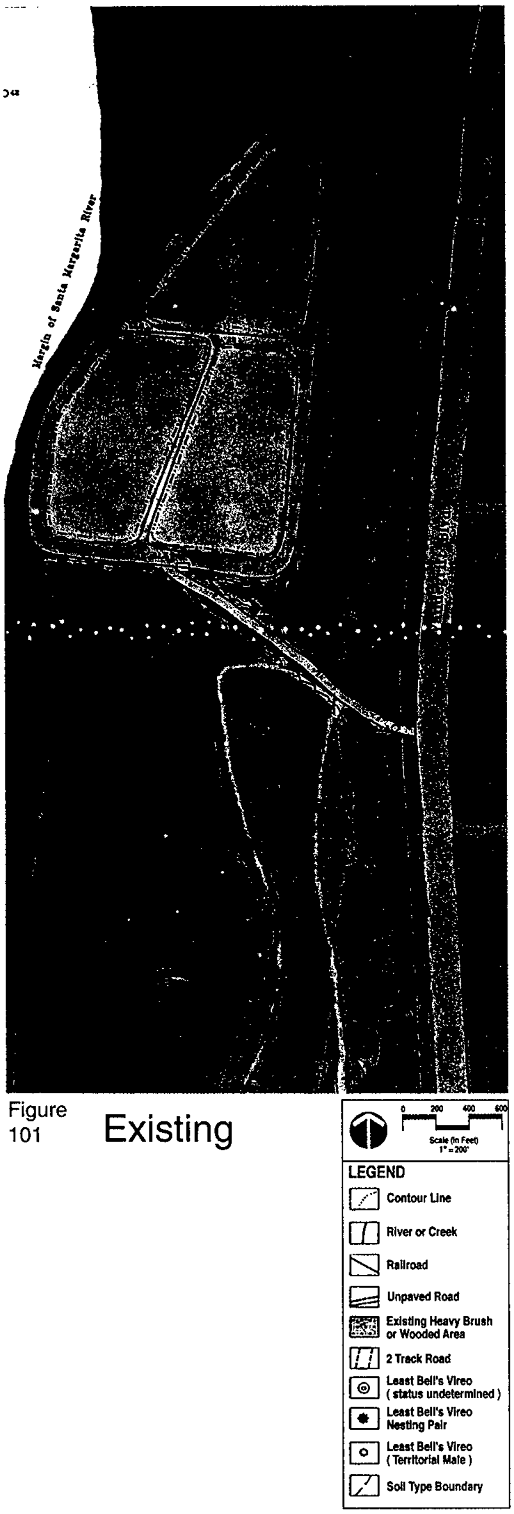


Figure 101 Existing

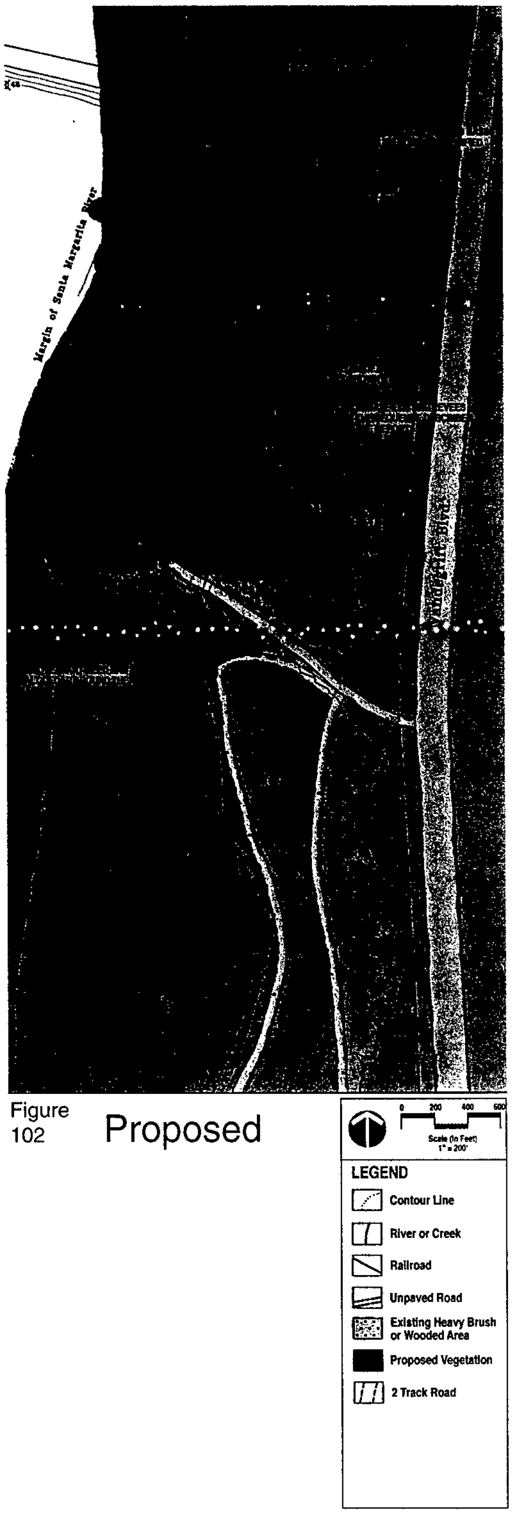
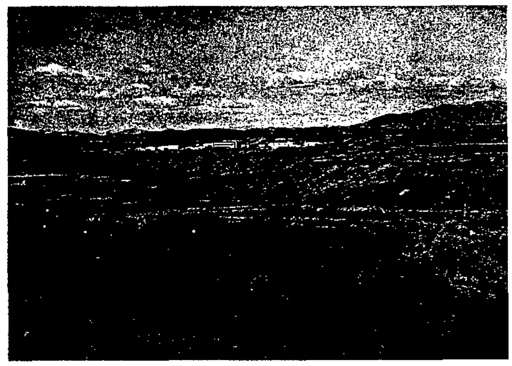


Figure 102 Proposed

Percolation Ponds at STP8



The STP8 ponds were originally built into a hillside, as shown in figure 103. A levee encloses the three down-slope sides. Dense riparian vegetation exists below the western levee and out into the shallow swale below. There are also several patches of wet meadow vegetation in the swale. There is evidence to suggest that the existing riparian and wet meadow vegetation is being supported in large part by water leaking from the ponds. As noted, use of the riparian habitat by least Bell's vireo has been documented, and waterfowl utilize the ponds.

The design, seen in figure 104, recommends removing the levees and regrading the site. The pond basin would be graded toward the hillside at a 1% slope with steeper transition slopes to meet the 30% grade of the existing hillside. All material from the levees and additional off-site fill would be required to achieve the designated grades. To protect existing riparian vegetation, no grading beyond the outer edge of the former west levee would be permitted.

The regraded site would be revegetated to a native grass/forb community on the flatter slopes and CSS on steeper slopes, following revegetation plant mixes and specifications currently used on MCB Camp Pendleton.

For all three projects, site grading and planting should be completed during the winter months to avoid disturbing birds during their breeding season. In all cases, an intense weed control program for at least three years after planting at all three sites would be mandatory. In addition, removal of giant reed, *Arundo donax,* and salt cedar, *Tamarix spp.*, from the meander corridor could significantly reduce ground water loss from evapotranspiration. This action could also reduce stress to existing riparian plant communities. The restoration of each of the three sites has been conceptually developed as as integral part of the adjacent plant communities, expanding patch size, increasing edge, and maintaining riparian biodiversity.

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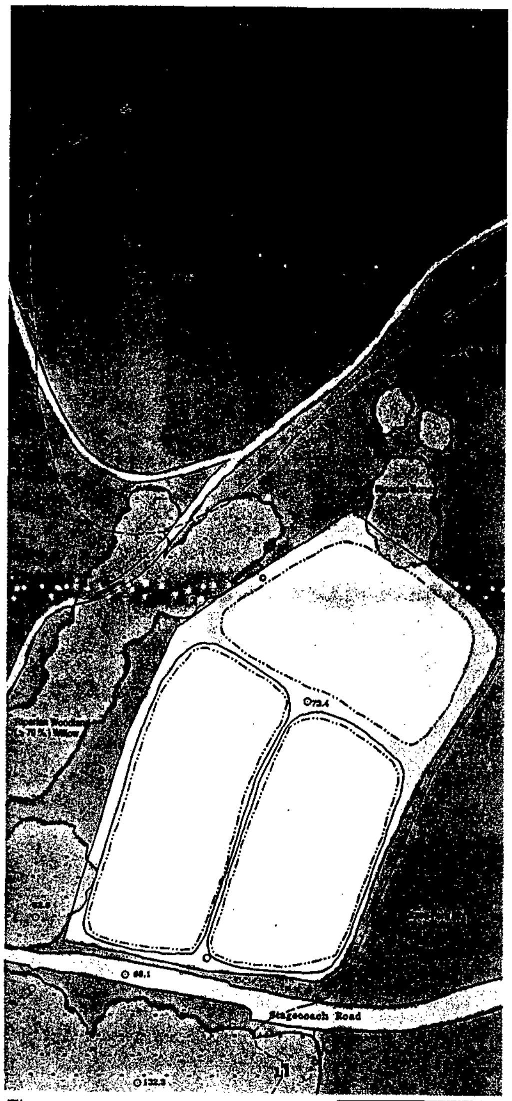

Figure 103 Existing

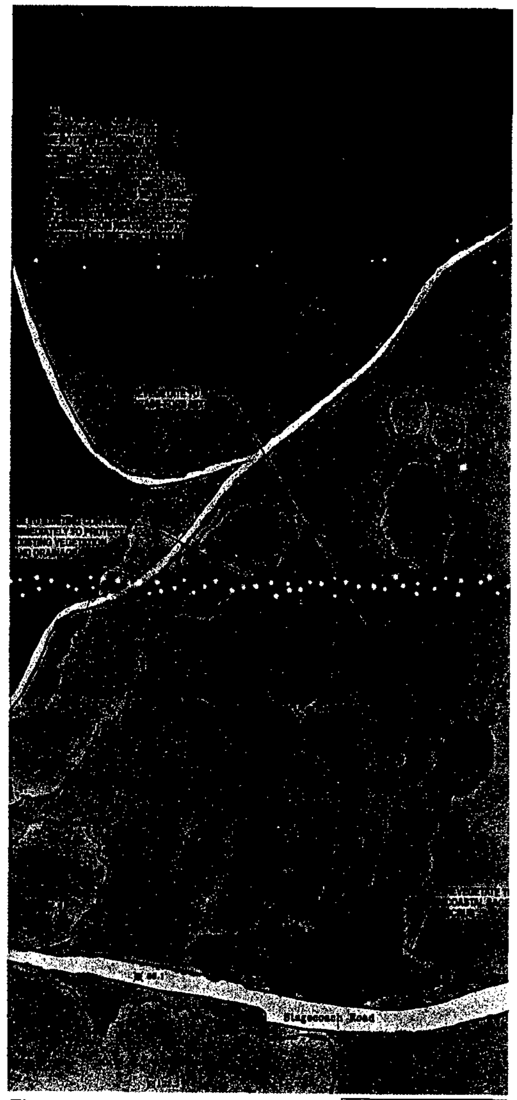

Figure 104 Proposed

Residential Subdivision on the Santa Rosa Plateau

At the southern end of the Santa Ana Mountains lies one of the most diverse concentrations of wildlife habitat in California. Some sixty sensitive, threatened, and endangered plant and animal species live in the mosaic of basalt mesas, grassland valleys, and wooded riparian corridors called the Santa Rosa Plateau. The California cougar is perhaps the best known and most publicized animal living here, but others such as Cooper's hawk, band-tailed pigeon, arboreal salamander, long-tailed weasel, San Diego pocket mouse, American badger, California gnatcatcher, San Diego horned lizard, and southwestern pond turtle attest to the biological diversity of the territory. The highest quality habitat in this area is protected and managed by a regional multi-agency partnership at the Santa Rosa Plateau Ecological Reserve. Encompassing nearly 3,150ha, the Reserve can serve as an oasis of plant communities for generations to come. Yet, in order to function as permanent habitat for the many species of birds, reptiles, and mammals that presently reside in the region, the Reserve must be linked to other natural areas including the Cleveland National Forest and MCB Camp Pendleton. Figure 105 shows a JERS 1 false color satellite image of the area and the boundaries of the Reserve, National Forest, and Camp Pendleton. The Reserve's native bunchgrass grassland is clearly evident in the center of the property as the large gray-green area.

Currently, the Plateau operates as an integral part of the larger Santa Ana Mountain ecosystem. Natural features and compatible land uses protect the habitat areas and their respective fauna. An escarpment to the north, the Cleveland National Forest to the west, and Camp Pendleton to the southwest have provided separation from the suburban development that has typified growth in this part of southern California for the past decade. Now, however, ongoing development on the escarpment and the lower plateau threatens the long-term viability of the Reserve as an element in the larger and connected landscape patterns that support the region's high biodiversity. Rural residential development is increasing on the northeast and sizable orchards have been established to the south. These orchards are shown as bright purple in the JERS 1 image. If this pincer-like development trend continues, the Reserve will become isolated from the other wilderness areas and may no longer have access to the sufficient influx of genetic diversity that is necessary for long-term species survival.

Figure 106 illustrates the **1990+** development on the Plateau. Shown in dark green are the Santa Rosa Reserve and the San Mateo Wilderness Reserve of the Cleveland National Forest, the principal biological reserves of this section of the study area. In lighter shades of green are other protected or managed properties including the remaining lands of the Cleveland National Forest and San Diego State University's reserve land. Camp Pendleton's military maneuver and impact areas are shown in light blue and purple respectively. Densely developed areas are shown in red, and slopes greater than 25% are shown in yellow. Potentially developable land is shown in gray.

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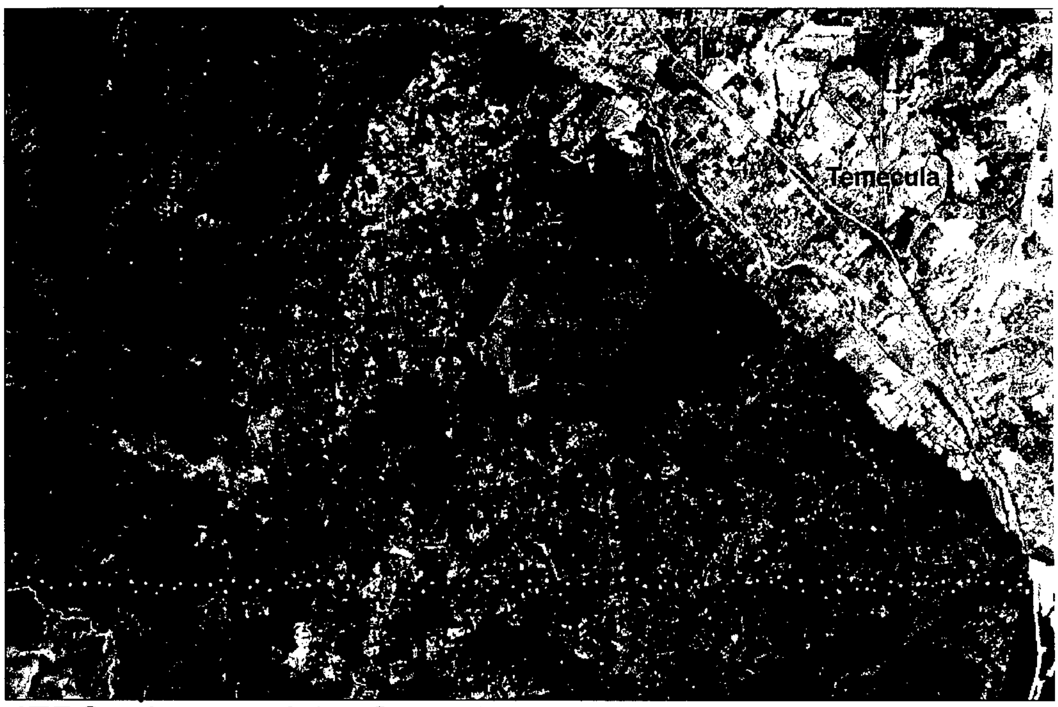
Figure 105



JERS 1 Image of the Santa Rosa Plateau

0 0.5 1 2 Kilometers
0 0.5 1 2 Miles

Figure 106

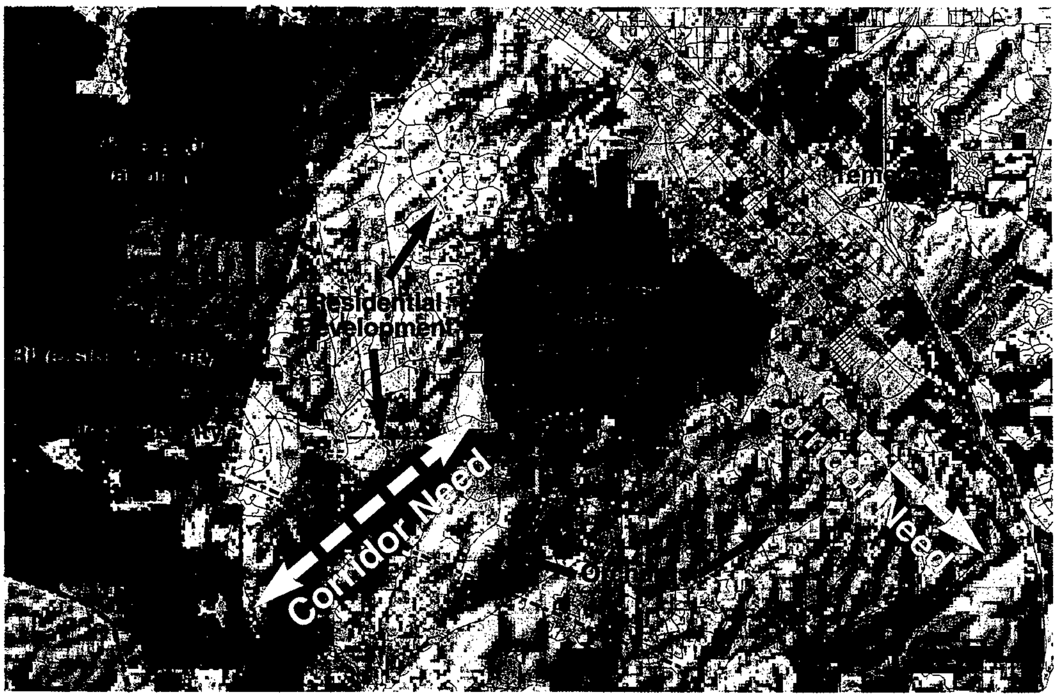


Diagram of Corridor Needs

0 0.5 1 2 Kilometers
0 0.5 1 2 Miles

To maintain the connections between these natural areas and thereby help to maintain the area's biodiversity, wildlife corridors must be identified and managed. The word corridor in this instance is equivalent to its usage in the landscape ecological pattern model: a linear strip of natural vegetation that provides linkage between natural patches. Strips may be along riparian corridors, but may also be comprised of grassland, sage, chaparral, or other native plant communities. It is also possible that a corridor may be comprised of several vegetation communities.

The planning and design of a wildlife corridor is, in part, a function of the goals of the conservation effort. Corridors may be designed for a single species, such as is being done in Florida for the panther, or for several species, as is done in parts of northern Europe. In identifying possible movement linkages for biodiversity on the Santa Rosa Plateau, it is advisable to maintain at least two representative stands of each native vegetation type, in the event that one is lost to disease. This is consistent with the noted relationship between habitat and biodiversity and will also contribute to the continuity of the pattern of vegetation across the landscape.

The planning and design of a wildlife corridor is also a function of land availability, landowner interest in participation, and land management. All of the land between the Reserve and the natural lands to the west is already subdivided for house lots. It is also possible that some larger lots may be further subdivided to a zoned density of one house per 2 hectares. While the existing parcelization and potential re-parcelization of this land may create some difficulties in establishing corridors, it does not create insurmountable obstacles.

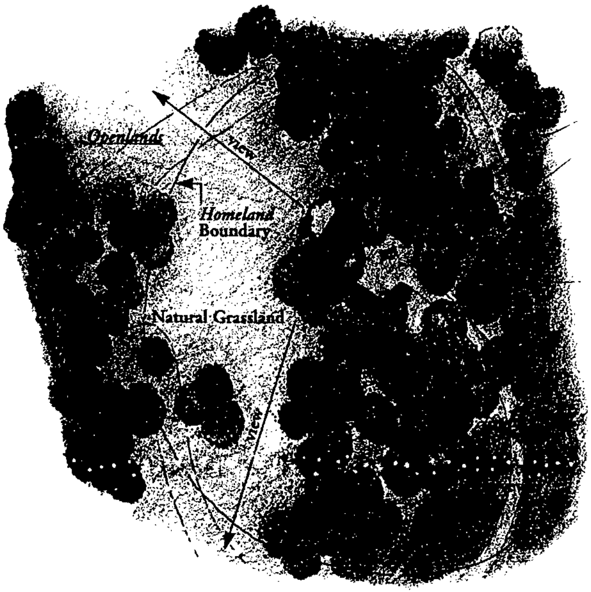
The siting of houses within the parcels, and not the parcel lines themselves, is in this case the most important consideration in creating the corridors. It is known, for example, that cougars avoid artificial light. Siting houses so that evening lights are not evident from the surrounding landscape will contribute to successful wildlife corridors. Also, architectural design elements such as roof overhangs, low exterior lighting, and special light retarding window glass can greatly contribute to the success of a corridor design. Locating houses so that driveways are shared will reduce the amount of vegetation displaced by impermeable surface and lessen the effects on the hydrologic cycle and thereby the long-term impact on habitat communities.

Homes should also be sited to allow active fire management. Fire is both necessary and inevitable in this landscape and the current practice of fire suppression in areas of rural residential development threatens both homeowners and the native plant communities. Periodic controlled burning reduces fuel loads and lessens the threat of destruction to life and property by catastrophic fire events and also simulates the natural fire patterns that allow many native plant species to regenerate. Fire related guidelines for siting houses include avoiding the middle of slopes and using existing and new roads as fire breaks. Prevailing winds in this area often direct fire toward the northeast, so extreme care should be taken if homes must be sited on south or southwestern slopes. Figure 107, from the Plan for the Santa Lucia Preserve (1995), near Monterey, California, shows several general guidelines for siting homes within such conserved habitat areas.

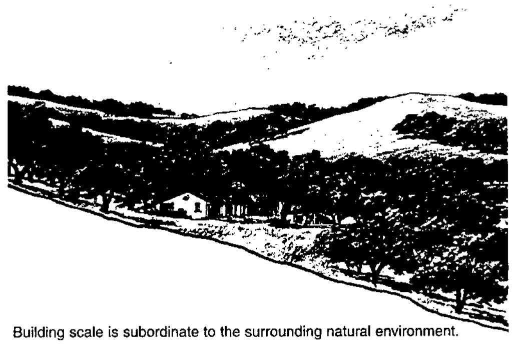
Lastly, the use of exotic plantings around houses should be avoided. Beyond the direct displacement of habitat by non-native plants, there is the risk that these species will become naturalized in the landscape and out-compete the native plants. The eucalyptus trees imported to California from Australia in the last century provide an example. Steep hillsides are the most likely areas for conversion to non-native species, because while they are difficult and expensive to develop for housing, they are easily planted with orchards that have minimal habitat value.

Maintaining connected natural vegetation could be the first step toward developing a working network of corridors between the Reserve and the nearby natural landscape without unduly limiting possible house sites. The combination of development opportunities and landscape conservation should result in both economically enhanced development and the maintenance of biodiversity.

Figure 107



Siting and design of homes and improvements within building envelopes will minimize potential impacts.



Building scale is subordinate to the surrounding natural environment.

Utilities are buried beneath roads and driveways which follow existing roads wherever possible.

Regulations for the siting of buildings and design of improvements will assure that the natural landscape always dominates the scene.

Illustrations from The Plan for the Santa Lucia Preserve, courtesy of Rancho San Carlos Partnership and Robert Lamb Hart • Planners & Architects, David P. Howerton, Partner

This study of alternative policies to guide residential development was conducted by graduate students in the Department of Landscape Architecture and Environmental Planning at Utah State University. It focuses on a relatively small and undeveloped watershed in the headwaters of Temecula Creek, part of the Santa Margarita River Basin. The area is designated as "Oak Grove," after a small rural community located near its center and is shown in figure 108. Current agriculture lands are illustrated in brown and areas of natural vegetation are in green. The distribution of land use in this study area will be based primarily on the existing building codes and zoning policies of this part of San Diego County.

Oak Grove could receive up to 1,500 new residents by the year 2010. To accommodate this growth, three development scenarios using different housing densities and associated land uses such as commerce, public institutions, and parks were created.

Three constraint sets for each scenario were then postulated and a comparison made of the benefits and risks to biodiversity of the density and constraint combinations.

Figure 108

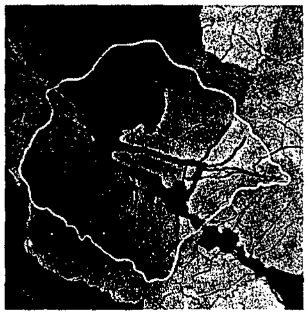
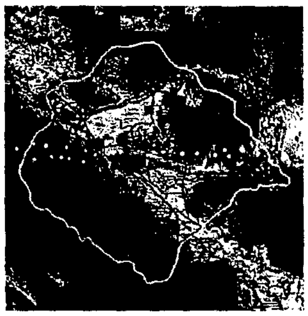


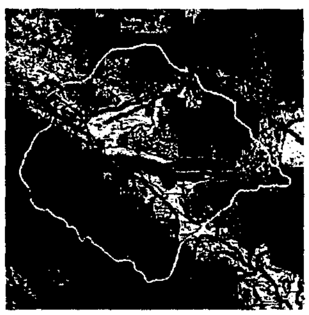
Figure 109



1

The "one" scenarios, **A1**, **B1**, and **C1**, show resource impacts resulting from current land use codes and traditional development practices. These include: no development on slopes above 25%, no development on public lands, and no development in stream channels and floodways (minimum 33m), and are shown in pinks and reds on figure 109. This level of regulation was used as the baseline to evaluate the effectiveness of more stringent guidelines.

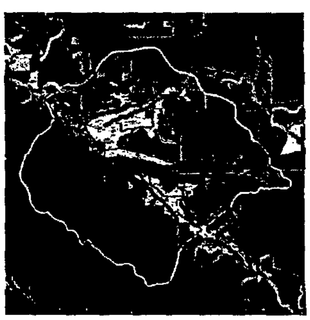
Figure 110



2

The "two" scenarios, **A2**, **B2**, and **C2**, attempted to enhance the protection of biodiversity and the hydrologic regime beyond that of the current land use codes. To accomplish these goals the stream channel and floodway protection area was extended to 75m and critical wildlife movement corridors determined by the landscape ecological pattern model were left undeveloped. These constraints are shown in red in figure 110.

Figure 111



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The "three" scenarios, **A3**, **B3**, and **C3**, resulted after analyzing negative impacts on deer and cougar habitat in scenarios **A2**, **B2**, and **C2**. In addition to the constraints described above, land uses were relocated from areas where there was a clear conflict with quality habitat. This pattern of constraints is shown in dark red in figure 111.

Scenario **Set A** allocates all residential development for 1,500 persons at a rural residential density of two units per hectare.

Scenario **Set B** allocates development for 1,500 persons at rural residential density with some single family residential density at ten units per hectare.

Scenario **Set C** assumes establishment of a large industry within the site, resulting in a larger population increase of 5,000 residents. This scenario allocates development in a mix of rural residential and single family residential densities. This scenario attempted to determine the carrying capacity of the site.

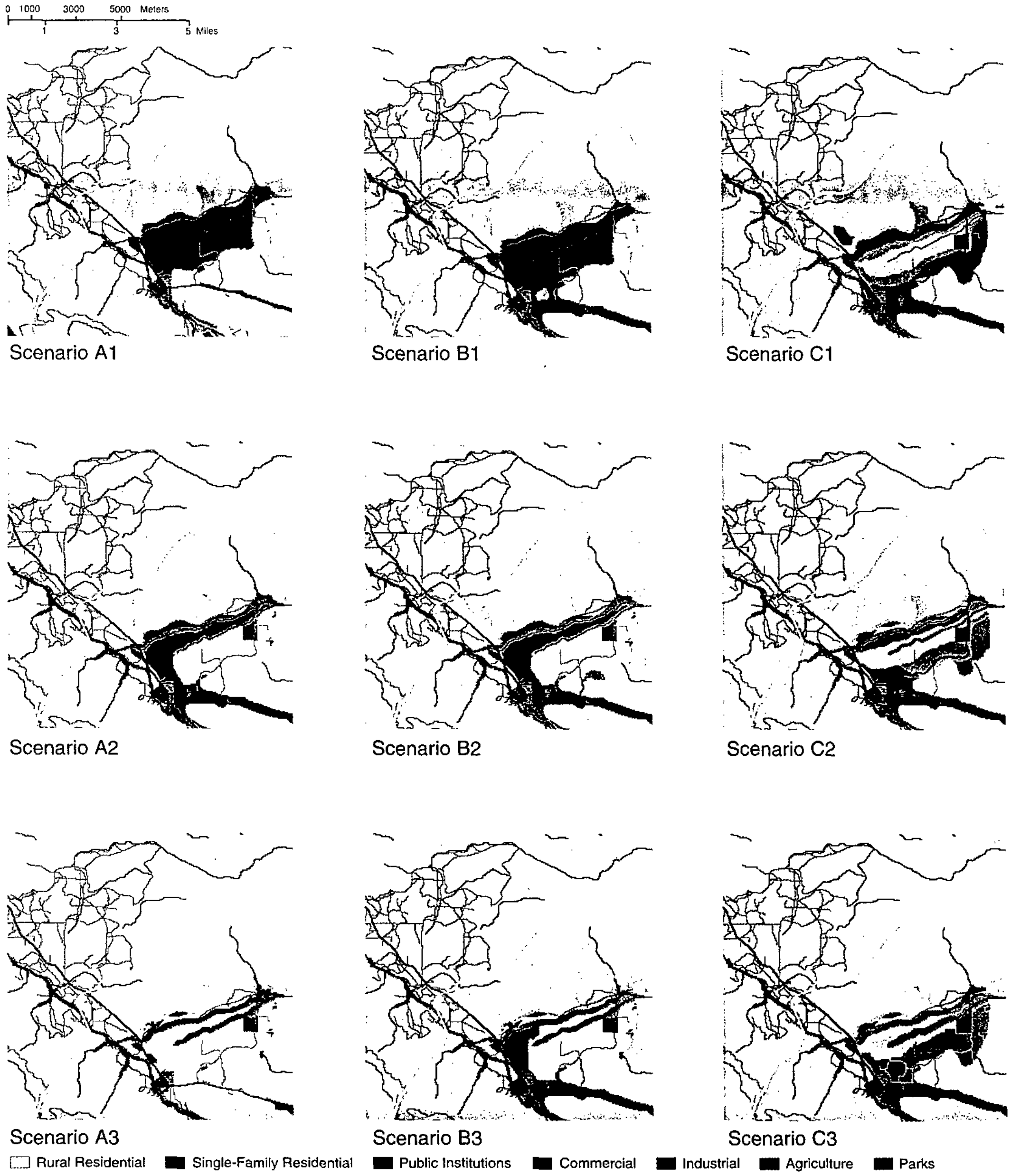

Figure 112

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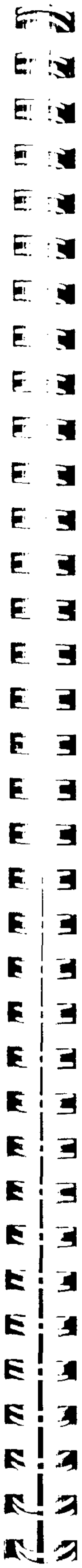
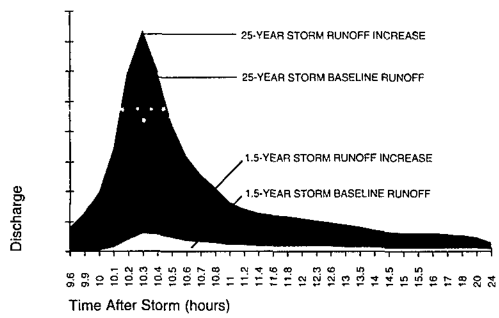
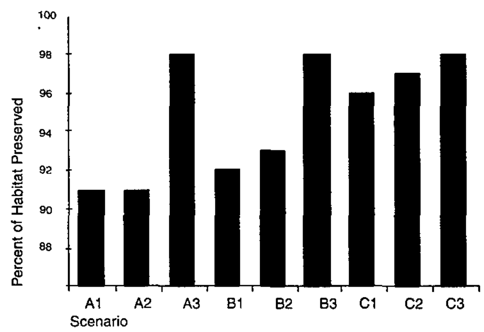


Figure
113



Change in Runoff Due to Development

Figure
114



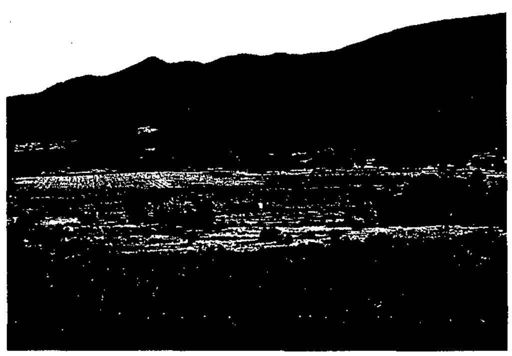
Impact on Habitat

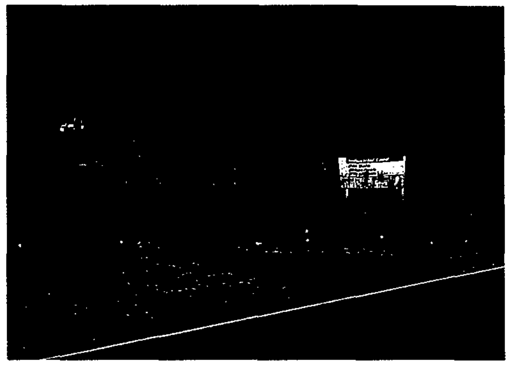
The nine alternatives in figure 112 were then compared via hydrologic and biodiversity models. The runoff model demonstrated an insignificant change from development compared to present conditions. Even C2 and C3, which accommodate over twice the population of the A and B scenarios, show an insignificant increase in runoff, as seen in figure 113.

The habitat models were effective when used for determining the placement of development, as seen in figure 114. This is evident even in the final "three" scenarios, in which biodiversity-determining conditions were maintained.

Two caveats should be considered: The "Oak Grove" case studies did not consider water needs, the requirements for sewage treatment, or fire management. These issues require further study to make definitive recommendations. It may also be the case that these results cannot be universally applied throughout the greater Camp Pendleton study area due to the steep slopes and public lands that characterize much of the Oak Grove watershed.

The study however, indicates that current San Diego County land use regulations –if enforced– do provide a substantial degree of protection for biodiversity. Impacts to biodiversity through direct removal of habitat or an altered hydrologic regime can be lessened substantially through steep slope restrictions, conservation of natural riparian floodway buffers, and public land protection.





Six alternative futures for the region of Camp Pendleton are compared in this report. They are all based upon the same set of assumptions as summarized in figure 12, 'Constrained / Buildable Land: 1990+.' Each alternative is shown in two stages: its projected state by the year 2010 which accommodates the forecasted population increase of about 500,000 additional persons, and its projected state at build-out as shown in the diagrams in figure 115.

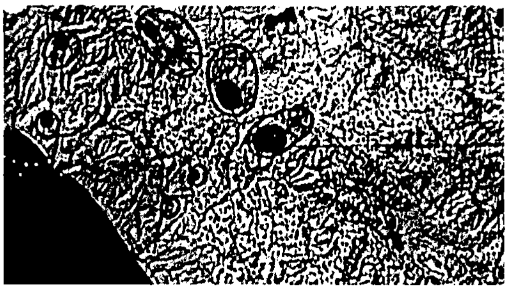
Plans Build-Out was described previously and is shown in the back cover foldout. It is based upon the current local plans as collated by SCAG, SANDAG, and MCB Camp Pendleton. It presumes the build-out of these plans with no additional constraints.

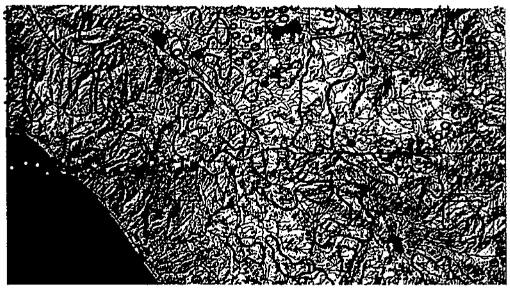
Five additional futures for the projected urbanization of the study region were planned by students at the Harvard University Graduate School of Design. All adapt aspects of these plans. Alternative #1 assumes the continuation of the predominant regional trend of **Spread** low density rural residential and clustered single family residential development. It also assumes the weakening of some development constraints and the absence of any new conservation-oriented land acquisitions. Alternative #2, **Spread with Conservation 2010**, also follows the spread pattern, but implements a conservation strategy beginning in 2010. Alternative #3 follows a low density pattern but proposes **Private Conservation** via large-lot ownership and management of land adjacent to and within important habitat areas as a means of conserving biodiversity.

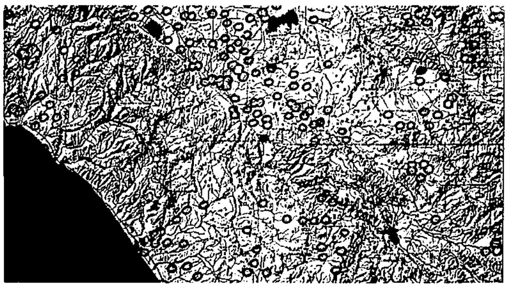
Alternative #4, a **Multi-Centers** strategy, focuses on cluster development and new communities, and Alternative #5 concentrates most growth in one **New City**. As a set, these alternative scenarios provide a reasonable range of options which the stakeholders of the study area should consider.

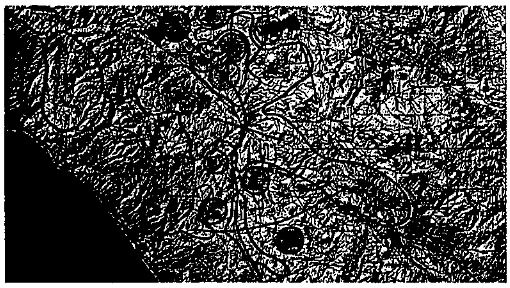
Two proposals are common to all of the alternative futures: a scenic highway route and a wildlife crossing of Interstate-15.

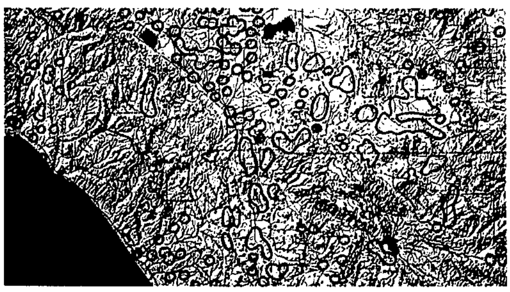
Figure 115

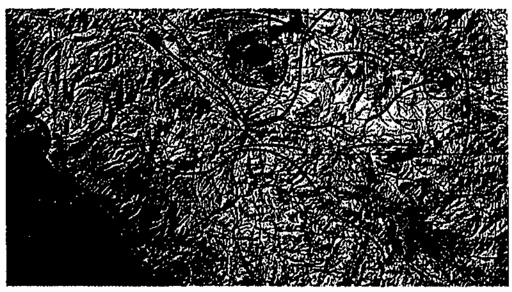

Plans Build-Out


Private Conservation


Spread


Multi-Centers


Spread with Conservation 2010


New City

A Scenic Highway Route

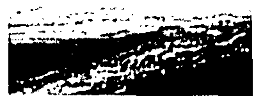
Of special importance to the alternative futures is a proposal to designate 210km of existing and planned roads in the study area as a scenic highway. As seen in figure 116, a tour of this route, and its optional links through Camp Pendleton and into the Temecula vineyard region, will enable visitors and residents to experience the unique and diverse landscapes of southern California. The route links many of the region's visual, ecological, and cultural resources and acts as a rural connector to the regional transportation spine of Interstate-15. There is a symbolic value as well. The route can strengthen the sense of this area as a single region.

Figure 116

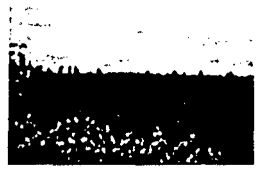

Mission San Juan Capistrano (1776)


Mission San Juan Creek at Rt. 74


Cleveland National Forest, Rt.74


Lake Elsinore


Camp Pendleton shoreline


Temecula Valley vineyards


Mission San Luis Rey (1796)


Lake Skinner


Cleveland National Forest Preserve


Palomar Mountain Observatory


Lake Henshaw


from Palomar Mountain State Park


Mission San Antonio del Pala (1816)

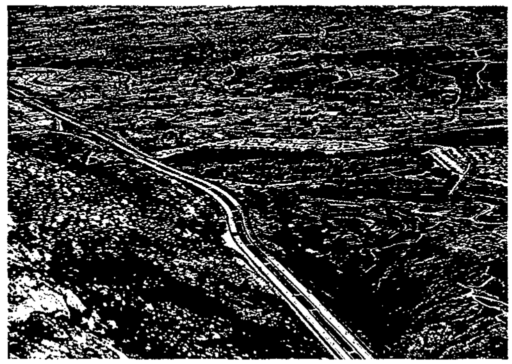

Pauma Valley

Interstate-15 Wildlife Crossing

The Santa Ana Mountains and the Palomar Mountain area are regarded as high quality habitat and are crucial to the maintenance of the region's high biodiversity. Much of the area is managed by the Cleveland National Forest, The Nature Conservancy, and Camp Pendleton. However, Interstate-15 has fragmented this habitat, making it difficult for the several species that require large home ranges, especially the California cougar, to use the full extent of the area. Currently, several cougar from small populations die each year on the Interstate. Male cougar must cross Interstate-15 to sustain genetic diversity within the Santa Ana population; without this, inbreeding will lead to regional extinction in a few generations (Beier, 1993). Crossing can be enabled by an overpass or underpass that will allow wildlife movement.

The following criteria should govern any design, and are based on the more stringent needs of the cougar:

Cougar travel at night, in places without lighting and favor routes in the scour zones of stream channels, along ridgelines, and on dirt roads and trails through dense chaparral. They use woody cover near road crossings for protection and avoid row crops and orchards.



Cougar avoid undercrossings less than 3m wide and noise levels greater than 60 decibels (Beier, 1993).

Two solutions are proposed and are shown in figure 117. The first is a partially enclosed underpass at the I-15 crossing of Temecula creek. The second is an overpass near this point.

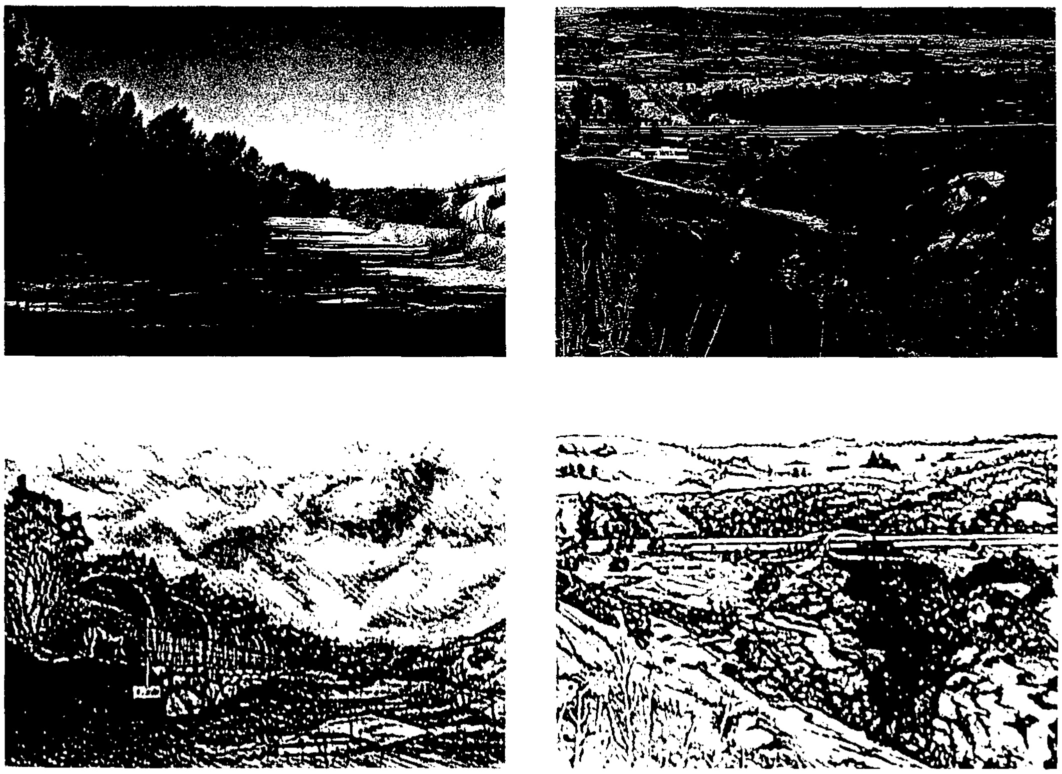
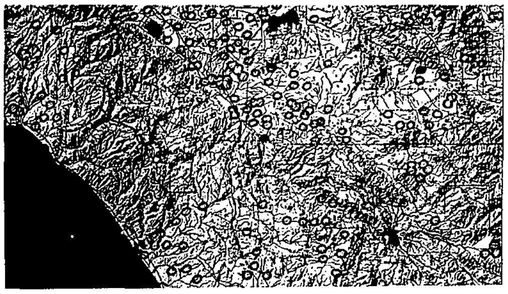


Figure 117

Alternative Future #1: Spread



Spread

Alternative #1 is based on the premise that development in southern California will continue its current spread pattern of single family residences in medium density developments in the valleys and extensive rural residential growth with altered vegetation throughout the landscape. It assumes no new conservation land will be purchased; no new major roads or other public transportation systems will be built; and that development will occur without special regard for the environment. Biodiversity, protection of native flora and fauna, erosion, flooding, and water quality will largely be ignored. Social concerns such as scenic preservation, commuting distance, and traffic congestion will not be considered.

In accordance with existing protection and management constraints, houses will not be built on slopes greater than 25%, but hillside orchards that accompany those houses are permitted. Development will also not occur in managed wildlife reserves, military bases, National Forests, state parks, or privately held reserves. However, other existing constraints on development will be relaxed.

Allocation of new houses will generally be consistent with the current trend: 50% at rural residential and 50% at single family density. There will be no allocation of multi-family housing. Commercial and light industry will be built along major transportation corridors following the existing zoning and development patterns for the area.

In order to locate land uses that reflect the spread of urbanization, an evaluation of attractiveness for single family and rural residential development was made. Rural residential houses at a density of one house per two hectares were distributed randomly within those areas that had the greatest attractiveness. Depending on the soil and slope, the land around the house became either avocado orchard, vineyard, grazing or non-native vegetation. Larger single family housing developments, which require location in areas of sewer and public water facilities, were allocated in quarter section (i.e., 0.4km x 0.4km) developments in most attractive areas. Figure 118 shows the development between 1990+ and **Spread** 2010.

The current spread pattern of development will continue after the year 2010 to build-out. There will be no new conserved land. Single family residential development will continue to extend across the valleys, and rural residential houses will continue to scatter across the landscape, dotting the ridgetops and fragmenting the remaining natural vegetation. All development prior to 2010 will remain, except in cases where land is zoned for more intensive use. Rural residential areas and all types of vegetation may be developed with multi-family housing or commercial and industrial use if zoning permits. However, single family housing will remain even if zoning allows for a more intensive use. Commercial development will line existing major roads and highways, altering the visual quality of the landscape. **Spread** Build-Out is shown in figure 119.

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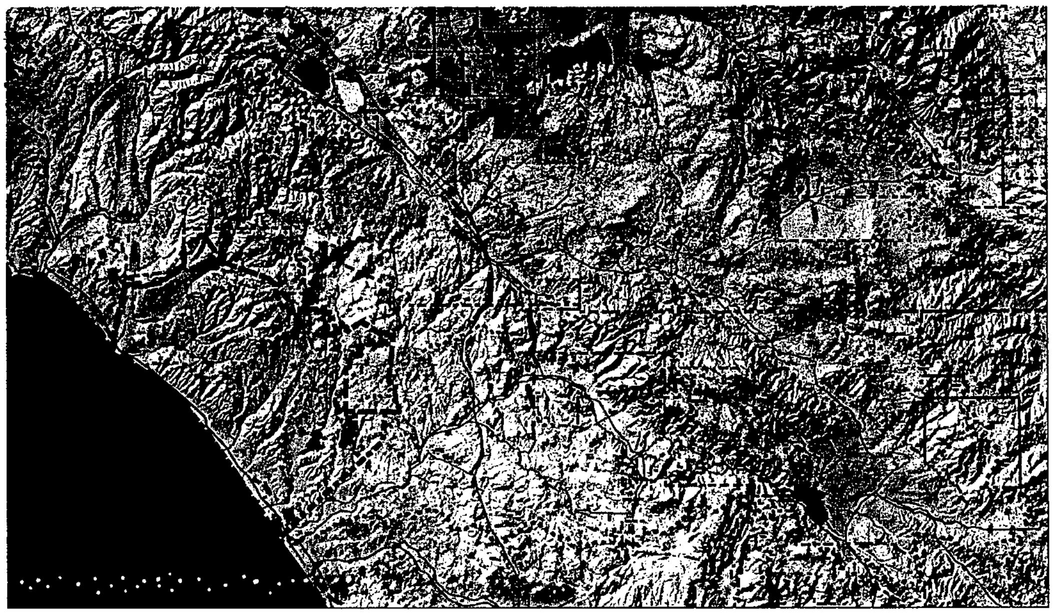
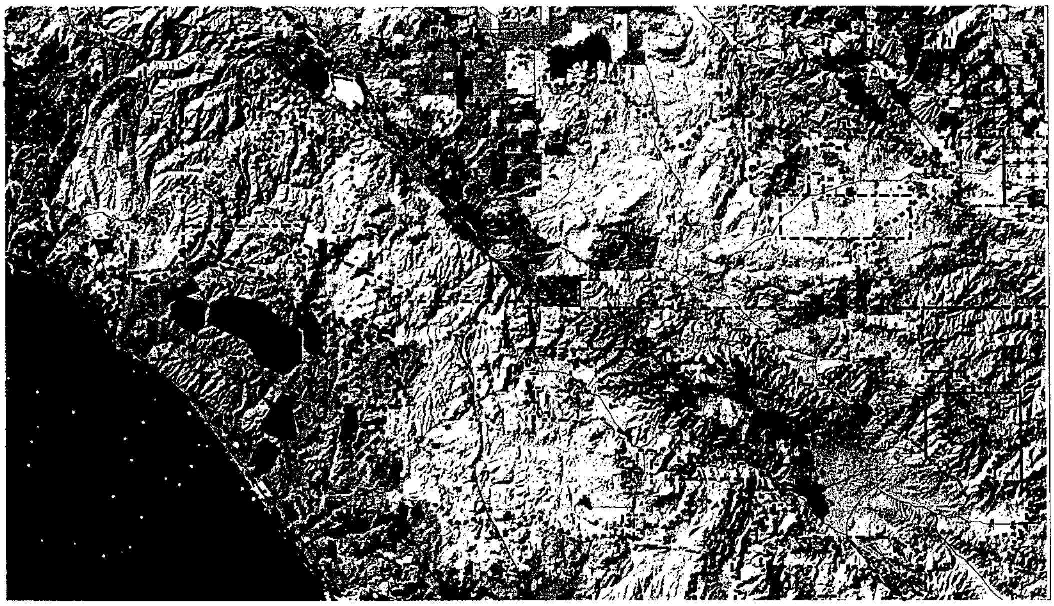
Figure 118



Allocation: Spread 1990+ to 2010

Buildable 1267148 ha 35%
New Residential 39464 ha 1%
Conserved 0 ha 0%
Watershed Boundary
Not Buildable 1621655 ha 45%
Altered Land 129285 ha 4%
Commercial Industrial 23116 ha 1%
Camp Pendleton
Built 477277 ha 13%
Orchard 7064 ha 0%
Transport 3623 ha 0%

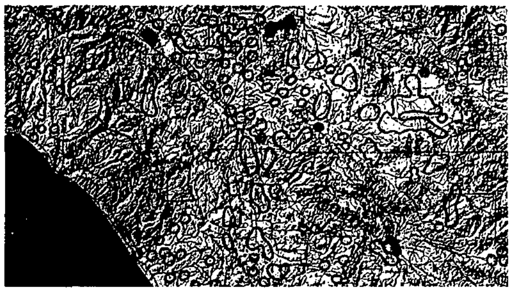
Figure 119



Land Cover: Spread Build-Out

Water
Mixed Forest 79437 ha 2%
Grassland 0 ha 0%
Single Fam. Residential 321903 ha 9%
Military Impact 40415 ha 1%
Riparian Vegetation 7466 ha 0%
Orchards 10244 ha 0%
Altered Land 129912 ha 4%
Multi Family Residential 110567 ha 3%
Commercial Industrial 155011 ha 1%
Oak Woodland 46420 ha 1%
Sage, Chaparral 895394 ha 25%
Rural Residential 1061250 ha 30%
Military Maneuver 125940 ha 4%
Transport 17084 ha 0%

Alternative Future #2: Spread with Conservation 2010



Spread with Conservation 2010

Alternative #2 follows the same spread, low density development assumptions that are the basis of Alternative #1, but only until 2010. This is seen in figure 120.

Development practices from 1990+ to 2010 have will have altered the regional hydrology, fragmented critical areas of the landscape ecological pattern, and threatened regional extinction of some native fauna. This will increase the public's desire to protect remaining areas of natural vegetation from development. Therefore, Alternative #2, **Spread with Conservation 2010**, assumes that all remaining areas of high conservation priority and all areas of riparian vegetation, coastal sage scrub, and chaparral, will be conserved beginning in 2010 by purchase or other means. All land outside protected zones and not developed as of 2010 is developed as zoned, to build-out.

Figure 121 shows in dark green the areas that were identified as having conservation priority in **1990+.** In light green are areas with some protection. Figure 122 shows the same analysis applied to **Spread** conditions in 2010. Note the amount of priority habitat that was developed between 1990+ and 2010, thus losing much of its value to biodiversity.

Figure 123, **Spread with Conservation 2010**, shows the state of the region at build-out following an as aggressive a conservation policy as it will be possible to initiate in 2010.

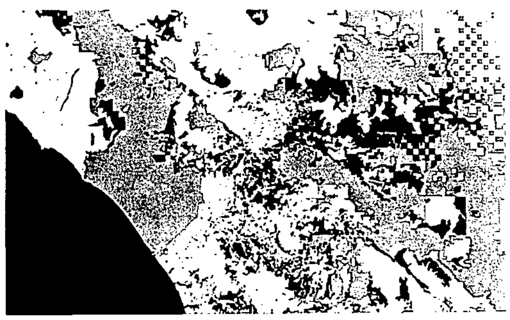


Figure 121

Conservation Priority 1990+

Figure 122

Conservation Priority 2010

Figure 120

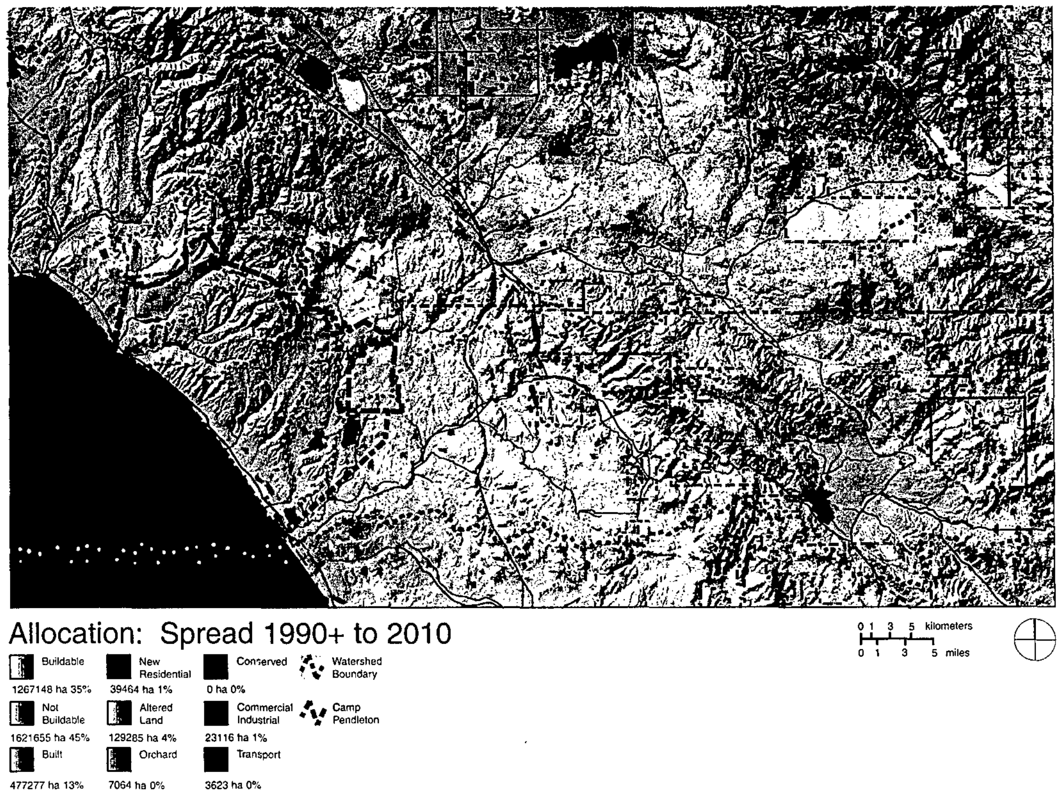
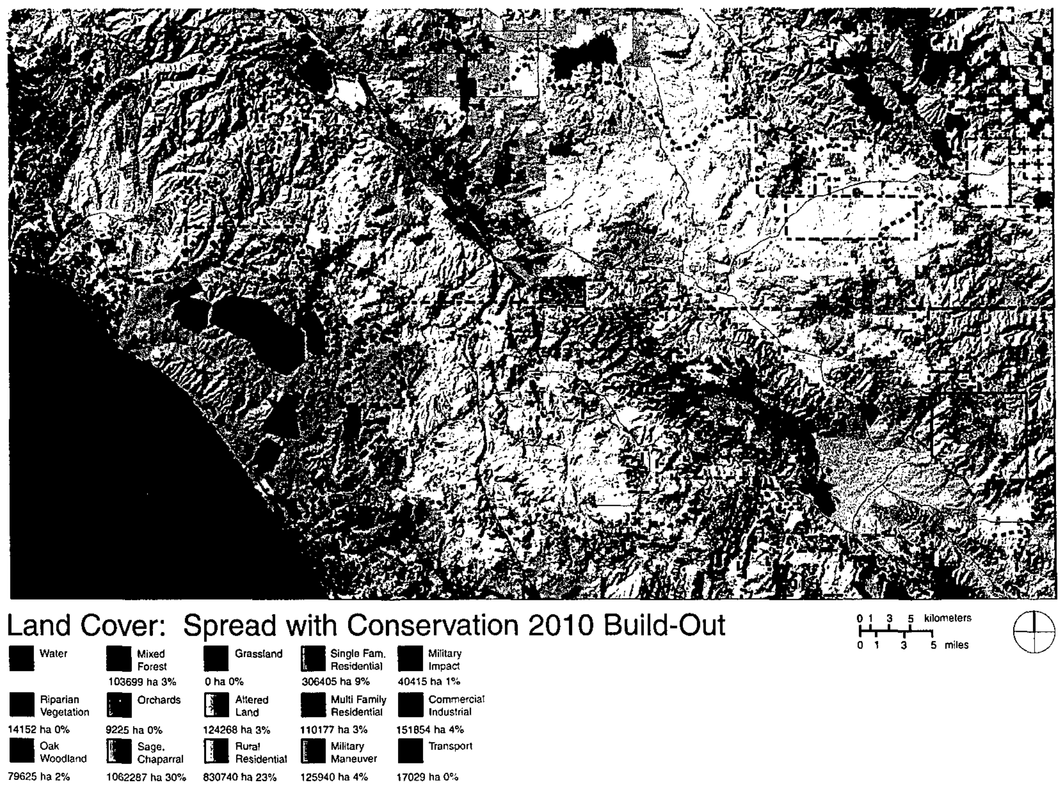


Figure 121

Figure 122

Figure 123



Alternative Future #3: Private Conservation

Private Conservation

Alternative #3 proposes to encourage private conservation to protect biodiversity, through private ownership of property and environmentally sensitive low density residential development in and near ecologically important areas. It assumes that the greatest threats to biological diversity and ecological integrity in the region are fragmentation and isolation of habitat. It further assumes that public resources to acquire land for conservation will be unavailable into the forseeable future.

The design team identified land critical for the maintenance of biodiversity through the landscape ecological pattern, single species potential habitat, and species richness models. Lands sensitive to development due to riparian vegetation, flood plain, prime soil, agricultural use, or high visual quality were also identified. The alternative proposes substantial private conservation efforts by encouraging the development of critical lands under strict guidelines to protect ecological integrity and cultural features. It presumes that the benefits of thoughtful development will outweigh the potential risks associated with very low density housing. This private conservation strategy becomes the key basis of growth to 2010.

Areas identified as critical for biodiversity or near riparian corridors are assigned the lowest density of rural residential development at one residence per 30ha. Houses allocated near the riparian corridors are sited along the outside of the zone of riparian vegetation. Areas identified as sensitive to development are allocated for rural development at a decreasing density gradient from urban centers. Land in or near an urban center has a maximum density of one residence per 10ha, land up to 5km out of the center would have a maximum density of one per 20ha, and land in the rural areas would have a maximum density of one per 30ha. Houses in sensitive areas are clustered in groups of two to six and share infrastructure. Each house has a maximum clearing zone of 30m, the same required by law in many jurisdictions for fire safety. No houses are allocated near roads in areas of highest visual preference.

Alternative #3 allows otherwise unconstrained and buildable land to be developed in accordance with existing plans. Land currently dedicated to conservation, recreation, open space, or military use will not be developed. New commercial and industrial development is restricted to non-sensitive areas near transportation corridors and within areas currently zoned for commercial and industrial uses. Areas for residential development which are not considered critical for biodiversity are developed according to existing plans. The land use allocation pattern for the **Private Conservation**, Alternative #3, in 2010 is shown in figure 124.

The allocation strategy is continued to build-out. There is an increasing shift to the spread alternative into the future because the most critical landscape will have been privately protected as soon as possible. The region at build-out for the **Private Conservation** alternative is shown in figure 125.

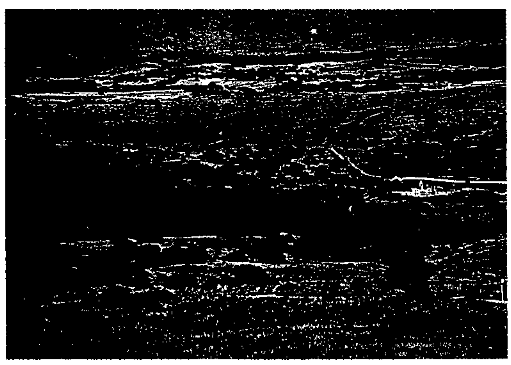
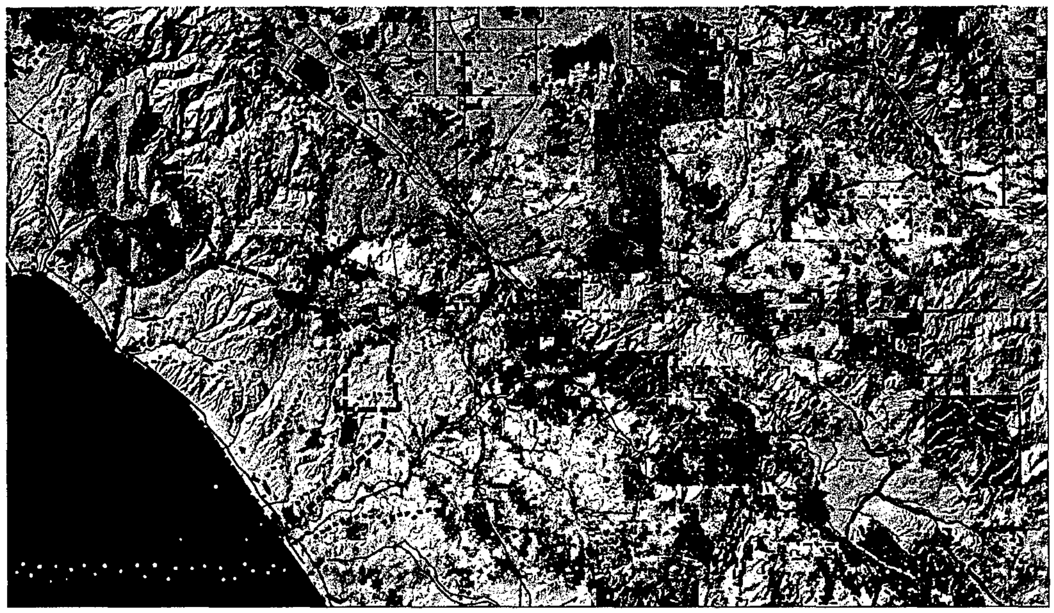
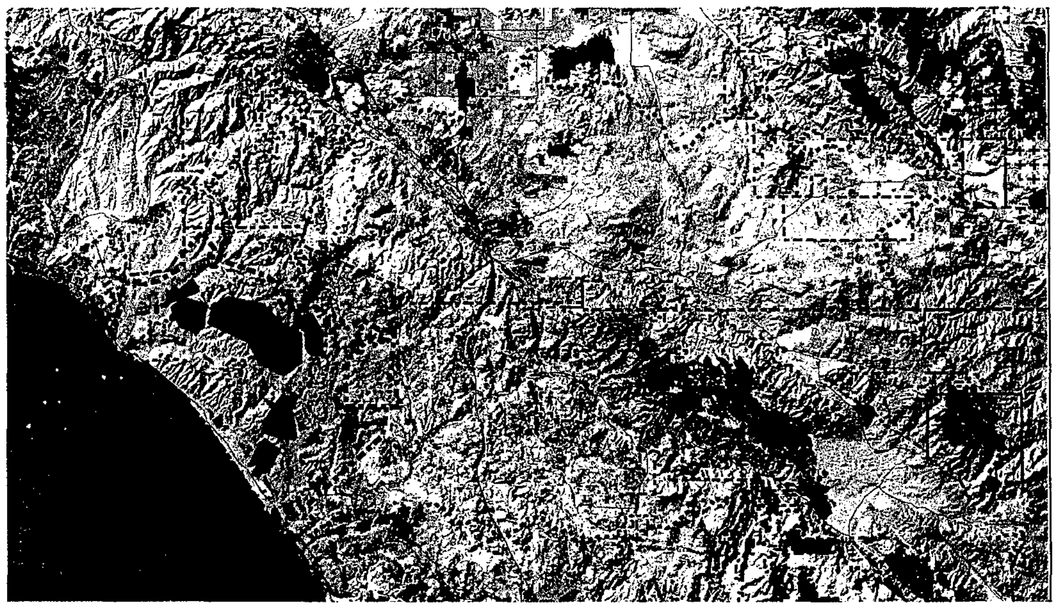


Figure 124



Allocation: Private Conservation 1990+ to 2010

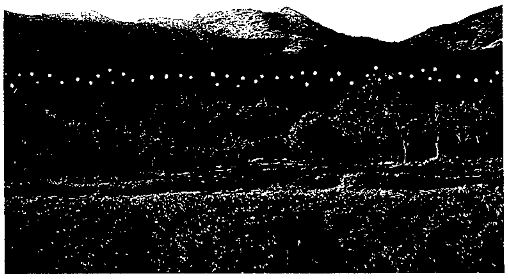
Figure 125



Land Cover: Private Conservation Build-Out

Several implementation approaches can be used by local governments in California to encourage and guide ecologically sensitive low density development (Johnson and Madison, 1991, Schiffman, 1989). All of the following have been used successfully to implement private conservation in California.

Local ordinances could require individual landowners to follow strict guidelines for density, house siting, area of altered land, vegetation removal, maximum slopes, etc. Local ordinances could also create overlay districts within the jurisdiction that require individual landowners within those areas to follow special guidelines. These districts might be based on agricultural areas, scenic areas, or areas of critical biodiversity.



Performance zoning can regulate land on the basis of permitted impacts rather than uses. A point system could be established that values each potentially harmful development impact. The greater the potential impact, the higher the value. New development proposals would have to be at or below an acceptable score before a building permit would be issued.

Cluster zoning can enable landowners to develop in smaller but denser areas, reducing the total impact on the larger ecosystem.

Transfer of development rights separates development rights from property and enables them to be transferred to another parcel. The development rights can be used by the same owner or can be sold to another.

Public-Private Partnership Land Trusts are locally based, not-for-profit, tax-exempt corporations that are legally empowered to accept and manage lands for the purpose of preserving open space. Land Trusts can purchase and hold land fee-simple; they can purchase the rights to develop land; they can purchase conservation easements; and they can accept gifts of land or easements. These transactions may give significant tax advantages to landowners. For an example, see *The Plan for the Santa Lucia Preserve* by the Rancho San Carlos Partnership (1995).

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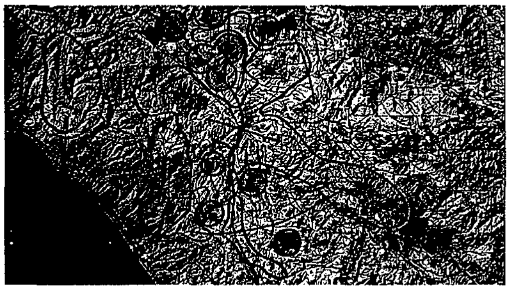
Figure 126

Only the land needed for a building and its immediate improvements will be developed.

Illustrations from The Plan for the Santa Lucia Preserve, courtesy of Rancho San Carlos Partnership and Robert Lamb Hart • Planners & Architects, David P. Howerton, Partner

Alternative #4: Multi-Centers



Multi-Centers

In order to focus urban growth and have the least possible impact on the ecological regimes, Alternative #4 identifies a small number of development "centers." These will have a density of people and commerce sufficient to create a critical mass of activity including pedestrian and public spaces. In the design strategy, each center has a unique character and set of functions. It is defined by clear boundaries, civic spaces, and one or two landmarks. These can be urban or natural, designed or conserved.

The conservation strategy for 2010 involves purchasing those lands that are susceptible to fragmentation by urban development. Emphasis is placed on providing linkages between currently protected habitats to ensure the sustainability of federally listed threatened and endangered species. This conservation strategy assumes that already protected lands will remain in protection. The strategy acknowledges the value of ecologically sensitive lands, productive agricultural soils, riparian systems, coastal sage scrub, chaparral, and visual and cultural resources.

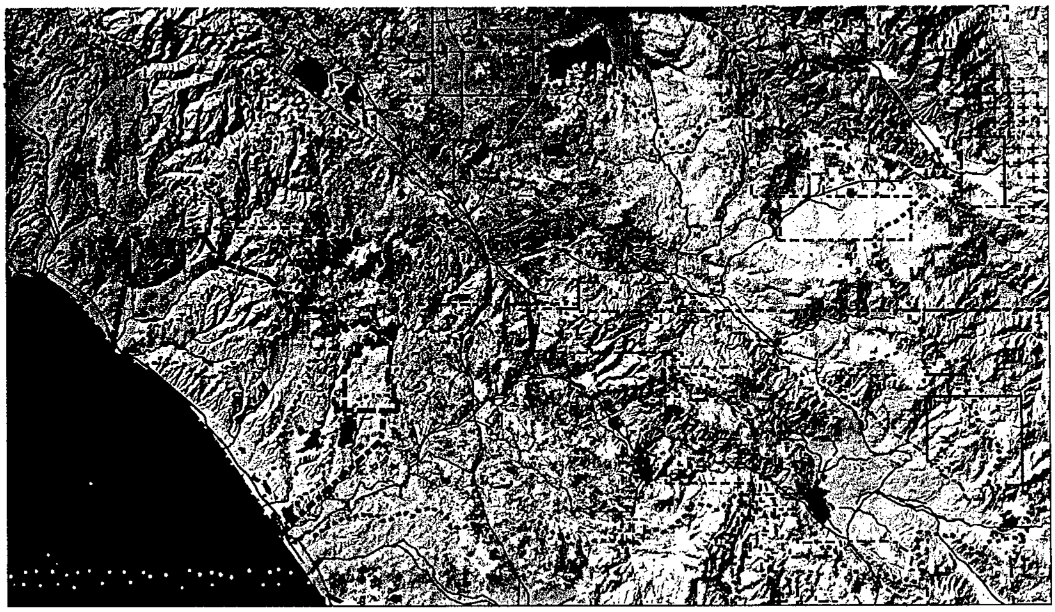
Centers were located to avoid the impacts to biodiversity, near intersections of major roads, and on developable land that was neither steep nor wet. Conservation purchases and greenbelts were added after the centers were located as a way to both connect them and provide identifiable edges. The combined pattern of development and conservation provides a highly linked network of natural areas and greenways directed at maintaining the region's biodiversity while accommodating population growth. For people, greenways act as recreational, cultural, and scenic amenities through urban and natural landscapes; for wildlife, they act as extensive habitat corridors, allowing animals to move through an increasingly urbanized landscapes.

Eleven regional locations are identified as "centers," seven in Riverside and Orange Counties and four in San Diego County. The centers in the northern section of the region along Interstate-15 are developed with emphasis on urban infill, while those in San Diego County will be dominated by conservation. The eleven centers, the housing areas in Camp Pendleton, and the major existing urban concentrations are linked by a network of existing roads that also accommodate commuter bus and light rail transportation.

Because the urban infill strategies are based on existing development, most of the 500,000 new residents expected by 2010 will be located in centers in the northern part of the region. Consequently, only 15% of the new population will be accommodated in the four southern areas. The changes in land use between 1990+ and 2010 for the **Multi-Centers**, Alternative #4, are seen in figure 127.

When carried to build-out, rural residential development increases outside the designated centers, and the resultant **Multi-Centers** land cover at build-out is seen in figure 128.

Figure 127

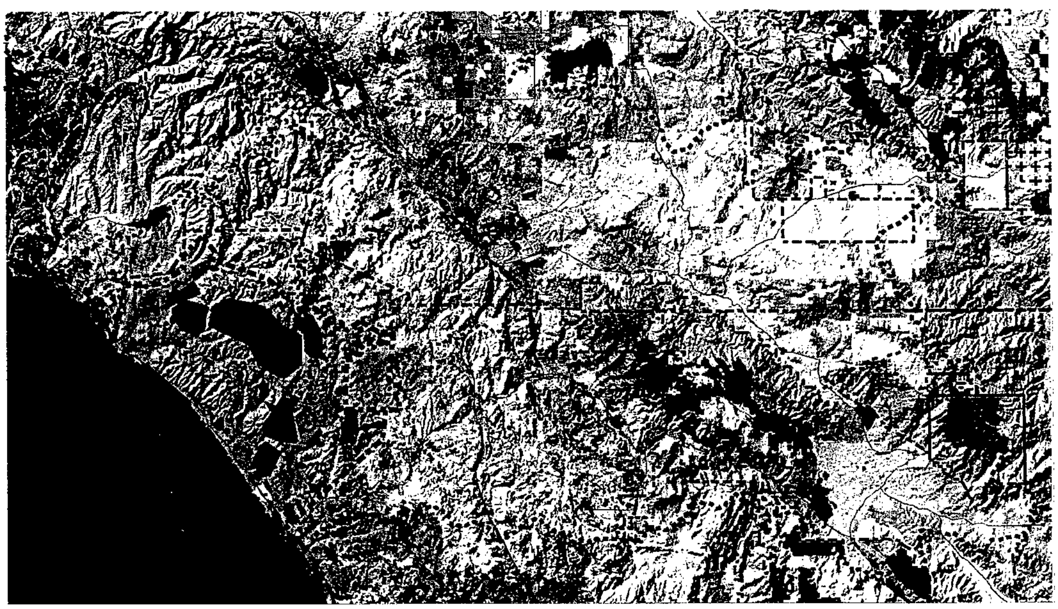


Allocation: Multi-Centers 1990+ to 2010

Buildable 1156618 ha 32%	New Residential 13586 ha 0%	Conservation 289601 ha 8%	Watershed Boundary
Not Buildable 1616588 ha 13%	Altered Land 22298 ha 1%	Commercial Industrial 10420 ha 1%	Camp Pendleton
Built 455351 ha 13%	Orchard 80 ha 0%	Transport 4089 ha 0%	

0 1 3 5 kilometers
0 1 3 5 miles

Figure 128

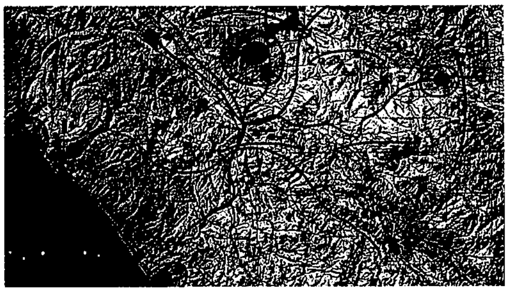


Land Cover: Multi-Centers Build-Out

Water	Mixed Forest 98100 ha 3%	Grassland 0 ha 0%	Single Fam. Residential 215932 ha 6%	Military Impact 40415 ha 1%
Riparian Vegetation 11711 ha 0%	Orchards 23236 ha 1%	Altered Land 91328 ha 3%	Multi Family Residential 106913 ha 3%	Commercial Industrial 125003 ha 4%
Oak Woodland 62488 ha 2%	Sage, Chaparral 1177309 ha 39%	Rural Residential 855777 ha 24%	Military Maneuver 125940 ha 4%	Transport 15326 ha 0%

0 1 3 5 kilometers
0 1 3 5 miles

Alternative #5: New City



New City

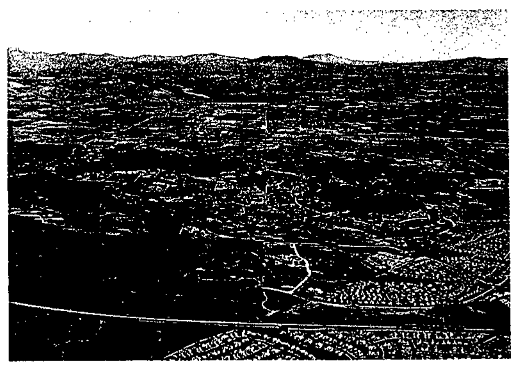
Recognizing that the success of any alternative strategy will rely heavily on market forces, Alternative #5 accepted the forecast assumption that the sub-regional areas predicted to experience the greatest percentage of growth by 2010 would absorb the majority of the 500,000 new residents. Small population changes outside of these areas would occur according to existing plans. The goal was to shape development, not the social forces that determine its location.

The coastal communities in the San Diego County portion of the study area are expected to receive about 110,000 new residents by 2010. The coastal communities of the Orange County portion are expected to receive about 12,000 new residents. Due to relatively high land prices and existing development patterns, design strategies in these areas focused on open space protection, community definition, high density infill, and concentration of commerce.

The Temecula Valley communities in Riverside County are predicted to receive the majority of new residents, an addition of around 317,000 people. To encourage this potential development within areas appropriate for urban development and away from areas critical for biodiversity, the design team proposed a location for a new single center that would incorporate existing urban areas as satellite communities. This became the focus of the proposed **New City** alternative.

An analysis was made to identify appropriate land for this major development. Consideration was given to the presence of transportation, sewer and water infrastructure, and avoidance of steep and flood prone areas. Conservation focused on protecting prime agricultural soils and species richness, as well as maintaining the existing landscape ecological pattern.

Since an overarching goal of the design was to maintain biodiversity, currently protected areas and areas identified as most critical for conservation were immediately eliminated from consideration for development. Large areas identified as important for conservation and unsuitable for development were not at issue and were also eliminated from consideration. Areas identified as least ecologically significant and suitable for development, which are concentrated west of the East Side Reservoir project in Riverside County, became the location for the **New City**.



The **New City** is shown in figure 129. The city center is located between the East Side Reservoir currently under construction and Lake Skinner, providing major recreational facilities for residents and tourists. The canal that connects the two water projects is expanded, creating an urban water body and linear park, which will be the major cross axis of the city.

To begin creation of an employment center, a primary commercial zone is located adjacent to the major conservation and recreation areas. Locating the center in this position would create a growth magnet in the region, taking advantage of existing excess supply in housing in the short term. New housing is located towards the core in increasing densities in order to provide housing opportunities close to the employment and amenities. A commercial core would include mixed-use commercial and residential development. Cultural and economic amenities like a museum, concert hall, theater, athletic stadium, and convention center would be created and located in the city center, as would a new regional university. A major element of the economic strategy is the location of additional new industrial areas designated for advanced industry with clean production and zero waste. These would be located close to major transportation networks (I-15, Santa Fe Railroad, March Air Force Base) to facilitate the shipping of materials and products.

Efficient public transportation, such as light rail or electric bus, will connect areas within the city and extend to existing rail lines and public transportation for access to Los Angeles and San Diego (and beyond). An interstate and secondary surface road system will connect the surrounding communities to the city center and the larger region.

The residential satellite areas, some of which already exist, would consist of single family home communities with public amenities, local services and transit stops. Public transportation and greenways would link communities with the city center.

Figure 129

To use conservation funds efficiently, the alternative focuses on threatened areas essential for the entire region and critical for the use of the **New City**. Though identified by the evaluation process as important for conservation, undeveloped land in the eastern portion of the region is currently less threatened by development. Therefore it was assumed that the decision to conserve open space in the east could be delayed beyond 2010.

Surrounding the city and supplementing existing protected areas, large areas of natural vegetation were designated for conservation. Based on priority, additional conservation areas were created to increase the connectivity in the open space network, especially between Lake Skinner and the Palomar Mountain area. These also define development limits of the center. Landscape corridors and isolated patches of natural vegetation continue this open space network throughout the urban pattern, as do recreation areas, public parks, and greenways. These buffer conservation areas, define communities, protect water systems, provide for species movement, and allow access to recreational amenities, thus integrating the city into the landscape pattern.

The city would be designed to work in a cleaner, more efficient manner. Strategies include total water catchment management, gray water and tertiary treatment systems, water recharge, waste management, and recycling. When combined with clean industry and true-cost economic analysis, the **New City** alternative could be a model for the development of future large communities.

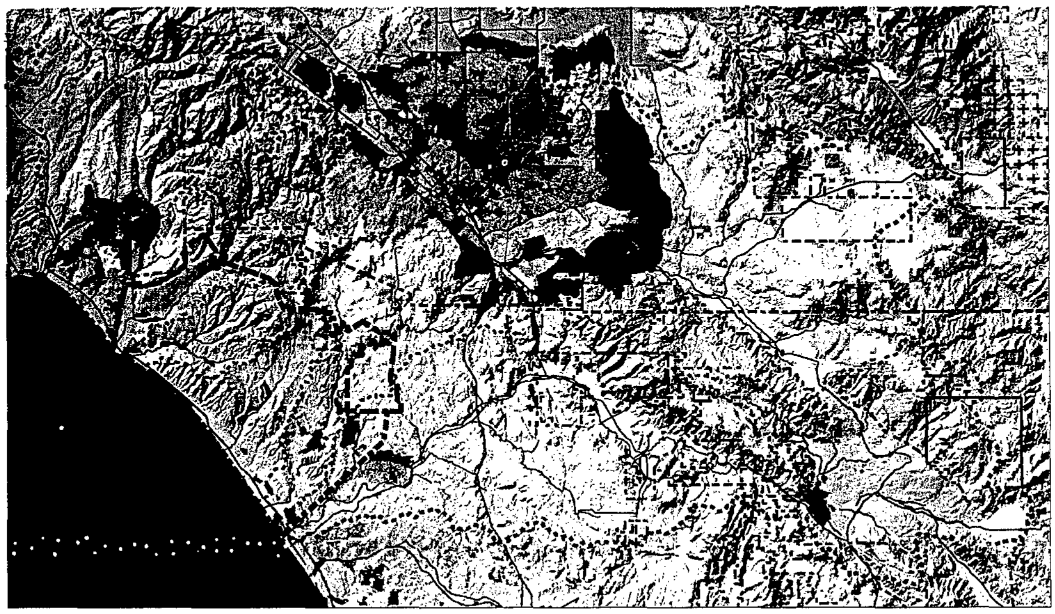
The first phase of this alternative, development of the **New City** by 2010, is seen in figure 130. The proposal carried to build-out, with additional conservation, is seen in figure 131.

While no one underestimates the complexities of implementing such a concentrated and coordinated proposal, these are some advantages to the **New City** strategy.

Through concentration of development, the costs per unit for land and infrastructure are reduced, thereby reducing the cost to the average home buyer or commercial/industrial investor. Both concentration and an efficient public transportation system reduce automobile reliance, thus reducing the number of automobiles required per family, the distance traveled for employment and services, and regional air pollution. In addition, the concentration of development allows for greater control over the impacts of that development through zoning, regulation, technology, conservation, and education. By creating a new employment focus distinct from Los Angeles and San Diego, commuting will be reduced, reducing pressure to develop new inter-regional highways and other extensive infrastructure programs.

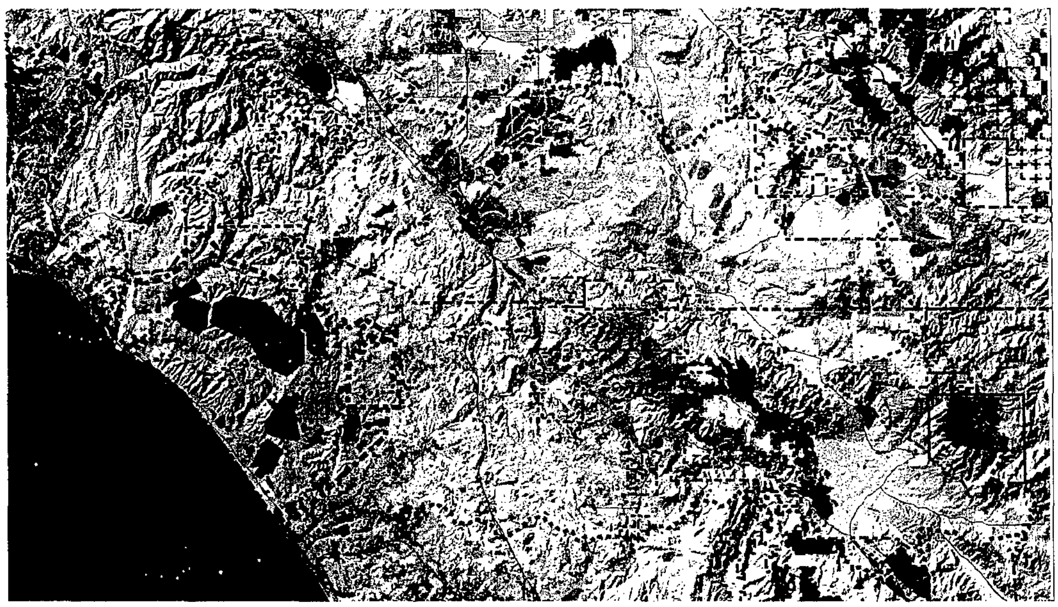
The location of the **New City** directs a significant portion of new development out of the Santa Margarita watershed. To the degree that the city can capture development, it may lessen the need to mitigate on-base flooding, or even to relocate the MCB Camp Pendleton airfield. However, long term development in the Santa Margarita basin at the planned rural residential densities will also need to be limited.

Figure 130



Allocation: New City 1990+ to 2010

Figure 131



Land Cover: New City Build-Out

Each of the alternatives has been assessed by each model for the impacts of changes between 1990+ and 2010, and between 1990+ and Build-Out. These are summarized in figure 132, which compares the six alternatives: **Plans Build-Out**, **Spread**, **Spread with Conservation 2010**, **Private Conservation**, **Multi-Centers,** and the **New City.**

Soils

In the **Plans Build-Out** scenario, half the potentially productive agricultural soils listed by the NRCS or the State of California will be lost to development. The protection of the other half is not through any new conservation strategy, but rather through the stewardship for other reasons by the current owners and managers: the Metropolitan Water District, the Bureau of Land Management, and MCB Camp Pendleton.

All of the alternative scenarios do better than **Plans Build-Out**. The **New City** and both **Spread** alternatives urbanize considerable areas of prime agricultural soils. The **Multi-Centers** and **Private Conservation** proposals lose the least amounts.

Hydrology

The **Plans Build-Out** and **Spread** scenarios both cover considerable areas of permeable soils with impervious land uses or compacted soils. This will lead to more run-off and less retention and more severe flooding. Development in currently unprotected land in the eastern portion of the study area will change the runoff in the headwaters area, reducing soil moisture and altering the vegetation pattern in both the **Multi-Centers** and **New City** alternatives. The **Private Conservation** scenario spreads small disturbance widely so soil runoff will be increased, but not as severely as in the other alternatives.

In **Plans Build-Out** nearly 5000ha of upland soils will change from very dry to dry or mesic as more water runs off developed uphill land. Much of the change will occur within typically dry vegetation types. About 2% of the total area of coastal sage scrub and about 13% of the total area of chaparral will become wetter which may change the vegetation.

Fire

The **Plans Build-Out**, both **Spread** alternatives, and the **New City** late-stage (after 2010) alternative enable rural residential development which will place both houses and the native vegetation communities at risk and make fire management difficult. While the **Multi-Centers** alternative protects some large areas in the northern half of the study area, fragmented conservation land in the southern half will also prove difficult to manage for fire. The **Private Conservation** alternative's strategy of clustering small numbers of houses at the edges of wide bands of conservation land affords a spatial distribution suitable for fire management within developed areas.

Landscape Ecological Pattern

Both the **Plans Build-Out** and **Spread** alternatives seriously impact the large natural areas in the eastern half of the study area. Even though one **Spread** alternative calls for conservation of available land after the year 2010, the landscape is expected to be so fragmented by that date that only the protection of small patches will be possible. The **Multi-Centers**, and to a slightly lesser extent the **New City** alternative, maintain smaller but contiguous patches of natural vegetation. The **Private Conservation** alternative, by privately protecting large natural areas and wide corridors at an early stage, best maintains the ecological pattern of the region. However, this alternative assumes that about 20% of the study area will fall within its policy proposals.

Single Species Potential Habitat

In general, the **Private Conservation** alternative best protects the single species potential habitats. In some cases, it expands potential habitats. The **Spread** alternatives and **Plans Build-Out** alter the patterns of habitat the most. It should be noted that several of the species will significantly expand their habitat because of the growth of rural residential development and its accompanying change to upland vegetation. Whether or not the great increase in cowbird habitat is good for biodiversity is questionable.

Species Richness

While suburbanization may only slightly change the total number of vertebrate species in the region, the habitat communities with the highest species richness will decrease significantly. The scenarios differ in the amount of that decrease, with the **New City** and **Private Conservation** proposals maintaining relatively more species richness than the others. All of the alternatives except **Private Conservation** decrease the number of species having at least 500 home range patches.

While species richness declines in all of the future scenarios, much is retained in the rural residential areas. This is especially true where smaller patches encompass species' home ranges. The definition of rural residential development posits an average of 25% conversion from native vegetation to structures, paving, and other land cover, and the retention of the remaining 75% of the natural vegetation. The analysis results are strongly dependent on strict adherance to this definition. Rural residential development that converts the remaining 75% to ornamental gardens, avocado orchards, or horse pastures would not maintain the predicted levels of species richness.

Visual Preference

The **Plans Build-Out** scenario will effectively destroy most of the highly preferred visual qualities of the area. Perhaps even more alarming, the **Spread** scenarios anticipate that some of the most visually attractive areas will be the first to be developed. The **Private Conservation** alternative, which is primarily directed at conserving the landscape ecological pattern, also protects exposed areas near roads. The **New City** alternative anticipates protecting some of the same areas after the year 2010, but the region will have lost much of its scenic value by then from development and fragmentation. The **Multi-Centers** alternative is the only one that substantially protects a continuous circuit of scenic views, but its proposed development in highly accessable areas still decreases the region's overall visual value.

Figure 132

Change in Land Cover

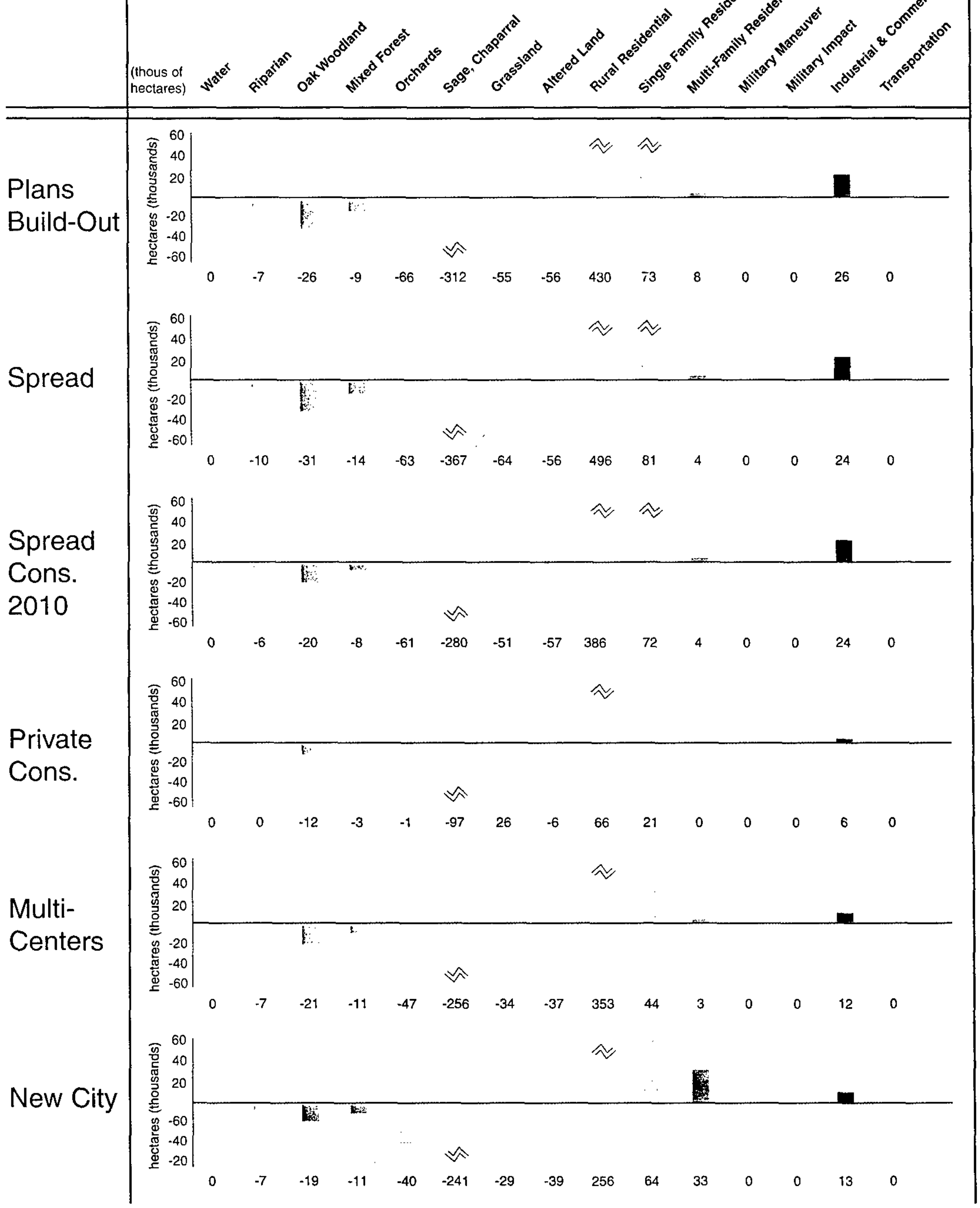


Figure 132

Figure 132 cont.

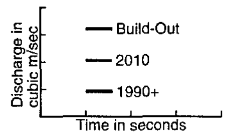
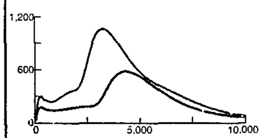
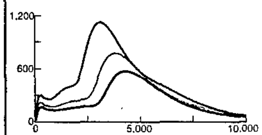
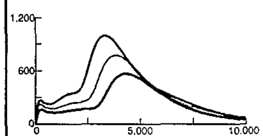
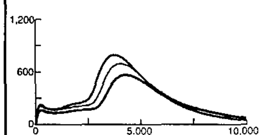
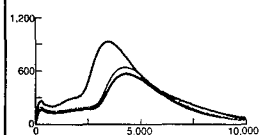
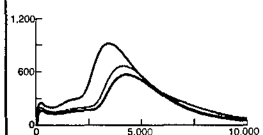
Change in Visual Value Retention (Ret) Preservation (Ps) Partial Ps (PPs) Modification (Md) Max. Mod. (MMd) (thousands of hectares)		Change in Prime Agricultural Soils (thousands of hectares)	Change inf Runoff Curve Number (RCN) Values (thousands of hectares)		Change in Santa Margarita River 25-Year Storm Hydrograph  	Change in Discharge from the Santa Margarita River (cubic meters)	Change in Fire Risk (thousands of hectares)	
Ret	-106		34 - 45	-33			Coastal and Riparian	7
Ps	-77	-117	46 - 60	-95		107,414,000	Fine Fuels	64
PPs	70		61 - 75	-84			Grasslands	77
Md	100		76 - 90	203			Shrubs	254
MMd	103		90+	13			Forests	10
Ret	-121		34 - 45	-48			Coastal and Riparian	10
Ps	-151	-61	46 - 60	-115		193,194,000	Fine Fuels	69
PPs	30		61 - 75	-99			Grasslands	92
Md	133		76 - 90	245			Shrubs	289
MMd	113		90+	18			Forests	14
Ret	-94		34 - 45	-38			Coastal and Riparian	5
Ps	-122	-59	46 - 60	-72		97,478,000	Fine Fuels	41
PPs	13		61 - 75	-100			Grasslands	105
Md	101		76 - 90	192			Shrubs	228
MMd	103		90+	16			Forests	11
Ret	0		34 - 45	-11			Coastal and Riparian	0
Ps	-46	-35	46 - 60	-25		53,267,000	Fine Fuels	5
PPs	-29		61 - 75	41			Grasslands	23
Md	25		76 - 90	52			Shrubs	61
MMd	26		90+	34			Forests	3
Ret	-72		34 - 45	-31			Coastal and Riparian	7
Ps	-114	-46	46 - 60	-73		82,867,000	Fine Fuels	39
PPs	33		61 - 75	-81			Grasslands	51
Md	88		76 - 90	155			Shrubs	218
MMd	55		90+	31			Forests	10
Ret	-63		34 - 45	-32			Coastal and Riparian	7
Ps	-100	-72	46 - 60	-62		80,445,000	Fine Fuels	33
PPs	-34		61 - 75	-72			Grasslands	42
Md	81		76 - 90	126			Shrubs	183
MMd	115		90+	39			Forests	10

Figure 132 cont.

	Change in Landscape Ecological Pattern (thousands of hectares)		Change in Arroyo Toad Potential Habitat (hundreds of hectares)	Change in Orange-Throated Whiptail Lizard Potential Habitat (thousands of hectares)	Change in Cactus Wren Potential Habitat (thousands of hectares)	Change in least Bell's Vireo Potential Habitat (hundreds of hectares)	Change in California Gnatcatcher Potential Habitat (thousands of hectares)
Plans Build-Out	Lg Nat Patch	-283					
	Nat Edge	640	-1	37	Nesting 0	5	Hi Qual Habitat -3
	Stream Edge	-93					
	Iso Nat Patch	21					
	Disturbed	-154			Habitat -8		Habitat -54
	Built	568					
Spread	Lg Nat Patch	-382					
	Nat Edge	24	0	37	Nesting 0	4	Hi Qual Habitat -14
	Stream Edge	-118					
	Iso Nat Patch	19					
	Disturbed	-154			Habitat -9		Habitat -72
	Built	620					
Spread Cons. 2010	Lg Nat Patch	-289					
	Nat Edge	46	0	43	Nesting 0	7	Hi Qual Habitat -3
	Stream Edge	-64					
	Iso Nat Patch	14					
	Disturbed	-152			Habitat -8		Habitat -34
	Built	453					
Private Cons.	Lg Nat Patch	-65					
	Nat Edge	75	1	76	Nesting 0	14	Hi Qual Habitat 0
	Stream Edge	0					
	Iso Nat Patch	-5					
	Disturbed	-173			Habitat 5		Habitat -1
	Built	170					
Multi-Centers	Lg Nat Patch	-266					
	Nat Edge	32	-1	56	Nesting 0	5	Hi Qual Habitat -1
	Stream Edge	-64					
	Iso Nat Patch	24					
	Disturbed	-165			Habitat 5		Habitat -23
	Built	440					
New City	Lg Nat Patch	-200					
	Nat Edge	-16	-2	28	Nesting 0	1	Hi Qual Habitat -2
	Stream Edge	-38					
	Iso Nat Patch	12					
	Disturbed	-174			Habitat -3		Habitat -28
	Built	384					

Figure 132 cont.

Figure 132 cont.

Change in California Gnatcatcher Potential Habitat (thousands of hectares)	Change in Bluebird Potential Habitat (thousands of hectares)	Change in Cowbird Potential Habitat (thousands of hectares)	Change in Fox Potential Habitat (thousands of hectares)	Change in Mule Deer Potential Habitat — Fawning (Fawn), Cover & Forage (CFor), Cover (C) (thousands of hectares)	Change in California Cougar Potential Habitat (thousands of hectares)	Change in Species Richness (no. of species per pixel)		Change in Vertebrate species having 500+ home ranges (no. of species)
						0 - 50	1	
li Qual abitat -3	85	420	-70	Fawn -7	Habitat -14	51 - 100	80	5
						101 - 150	333	
				CFor -10		151 - 200	-283	
abitat -54				C 168	Stepping Stone -1	201 - 250	-119	
						251 - 300	-8	
						301 - 325	-2	
						0 - 50	-3	
Qual abitat -14	84	494	-77	Fawn -8	Habitat -19	51 - 100	90	5
						101 - 150	377	
				CFor -14		151 - 200	-309	
abitat -72				C 1	Stepping Stone -2	201 - 250	-141	
						251 - 300	-11	
						301 - 325	-3	
						0 - 50	-3	
Qual ıbitat -3	80	316	-40	Fawn -6	Habitat -16	51 - 100	80	3
						101 - 150	330	
				CFor -3		151 - 200	216	
ıbitat -34				C 10	Stepping Stone 2	201 - 250	-80	
						251 - 300	-9	
						301 - 325	-2	
						0 - 50	-17	
Qual bitat 0	107	73	-1	Fawn 0	Habitat 23	51 - 100	22	0
						101 - 150	68	
				CFor 13		151 - 200	-51	
bitat -1				C -8	Stepping Stone -3	201 - 250	-20	
						251 - 300	-3	
						301 - 325	0	
						0 - 50	-3	
Qual bitat -1	86	323	-53	Fawn -4	Habitat -8	51 - 100	52	4
						101 - 150	268	
				CFor 5		151 - 200	218	
itat -23				C 2	Stepping Stone 6	201 - 250	-91	
						251 - 300	-6	
						301 - 325	-2	
						0 - 50	-10	
Qual itat -2	81	219	-32	Fawn -1	Habitat -18	51 - 100	101	4
						101 - 150	198	
				CFor -10		151 - 200	227	
itat -28				C 9	Stepping Stone 2	201 - 250	63	
						251 - 300	-6	
						301 - 325	-2	

The comparative impacts of the several alternative futures are summarized from the perspective of landscape planning for biodiversity in figure 133. The **Plans Build-Out** and the **Spread** alternatives, which do not have the management of biodiversity as primary objectives, perform poorly from that perspective. The alternative which seeks to protect the most significant habitat areas via **Private Conservation** succeeds, but at the risk of impacts associated with very low density and clustered development in some of the region's most sensitive environments. If the development process can be managed well, these private land management policies may be the most effective. The **Multi-Centers** and **New City** strategies seek to conserve biodiversity by attracting more concentrated development into appropriate locations while minimizing public cost for conservation and infrastructure. In the period to 2010, these seem to be plausible strategies for biodiversity, although no one underestimates the difficulties in implementing development patterns which diverge substantially from the **Plans**.

If the alternatives presented here are to be considered by the regional stakeholders and their decision-making processes, there is significant benefit in doing so soon. The spatial patterns and magnitudes of the impacts of the several alternative scenarios have greater variance in the short term between **1990+** and 2010, than in the longer period toward build-out.

When considered in a longer time frame, in which the scenarios are carried forward to their build-out,

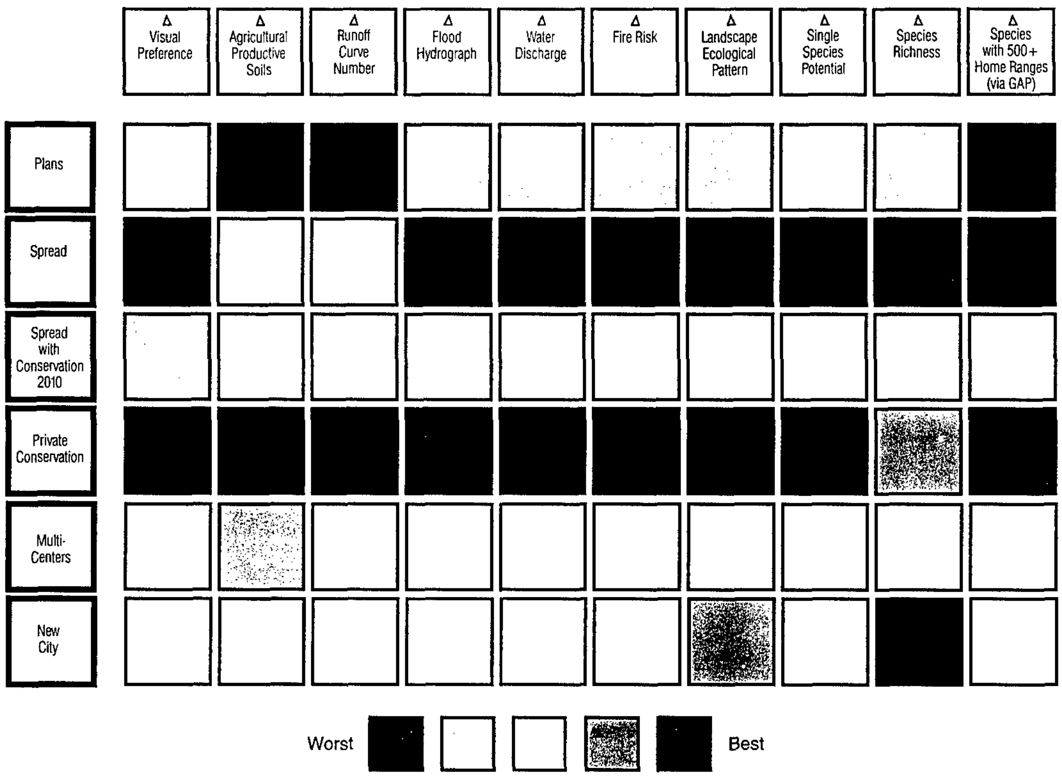


Figure 133

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Δ Species with 500+ Home Ranges (via GAP)

Figure 133

all of the alternatives cause serious impacts, as was seen in figure 132. All will lose agriculturally productive soils and cause increased erosion and sedimentation. All of the development scenarios will cause a change in soil moisture, a reduction in water tables in the river basins and a dramatic increase of flood discharges. The net effect will be a reduction of biological diversity in the region of Camp Pendleton as the hydro-period of the riparian zone becomes shorter, and floods wash out flood plain sediments and associated native vegetation. Re-colonization by native vegetation, which once happened naturally, will be inhibited by introduced naturalized plants such as the giant cane, Arundo donax, that can opportunistically dominate a flood plain to the exclusion of native vegetation. This will radically change the riparian zones which are (or were) the areas of greatest species richness. Upland biodiversity will also be altered in all scenarios due to reduced soil moisture and increased fire suppression associated with rural residential development. In all scenarios, the landscape will lose most of its visually preferred character.

The direct consequences on biodiversity of all the scenarios are also all negative. In all of them, but to different degrees, the landscape ecological pattern is increasingly fragmented. Natural areas are decreased in area and increasingly isolated in an urbanized region. Some of the most important single species, such as the gnatcatcher and cougar, will be seriously impacted, and their long-term regional survival will be in doubt. The pattern of species richness will be dramatically altered by invasive species.

On the positive side, the population forecast for 2010 can be easily accommodated and the build-out populations for all scenarios are potentially several times larger. If one assumes the continued importation of water (as the regional plans and alternative scenarios do), the region can accommodate growth into the longer-range future.

When the several regional alternatives are assumed to be developed to build-out, all of the environmental measures upon which this research has focused will decline dramatically. While all of the alternative futures converge to a generally similar pattern of impacts caused by the transformation of a predominantly "natural" regional landscape to a predominantly "urbanized" pattern, the variance among the alternatives, both spatially and in magnitude, is almost entirely the result of policies which (are assumed to) take effect between **1990+** and 2010. The **Private Conservation** alternative, which proposes to maintain the integrity of the region's larger natural areas and their connections along the riparian network, is also the most protective of the long-term regional biodiversity. As was seen in **Spread with Conservation 2010**, waiting fifteen years will not be effective; it will be too late to make a difference.

There are many opportunities at the sub-regional level to manage or improve the conditions for high biodiversity, several of which are demonstrated in this study. There are many more opportunities for habitat restoration such as those shown at Camp Pendleton. The barrier to wildlife movement now caused by Interstate-15 can be "bridged." There are ways for rural residential development to be compatible with species movement and habitat protection, as shown in the "Oak Grove" study. An area can accommodate development and still maintain biodiversity by acknowledging some common sense constraints to development on steep slopes and flood-prone riparian zones.

The dependence of species richness on the precise style of rural residential development underscores an important point: the individual owners of these lands can have a critical impact on the long-term level of species richness. If they retain the native vegetation, they will maintain substantial numbers of species; if they use the land for other purposes, they will not.

If biodiversity –which does not recognize jurisdictional boundaries– is to be maintained in the region of Camp Pendleton, innovative decision-making will be needed. At the regional scale, there must be much more coordination of planning for both development and conservation. This is easy to say and difficult to accomplish. Some of the most significant issues cross jurisdictional boundaries: upstream development in the Santa Margarita watershed causing downstream flooding in other jurisdictions, the East Side Reservoir's conservation areas in Riverside County linking to proposals generated by San Diego County, riparian channelization in one jurisdiction breaking a regional habitat pattern, and joint water supply and fire management planning. From the perspective of biodiversity, even the largest public landscapes, such as the Cleveland National Forest and MCB Camp Pendleton, cannot be seen as isolated, self-contained, and self-managed entities.

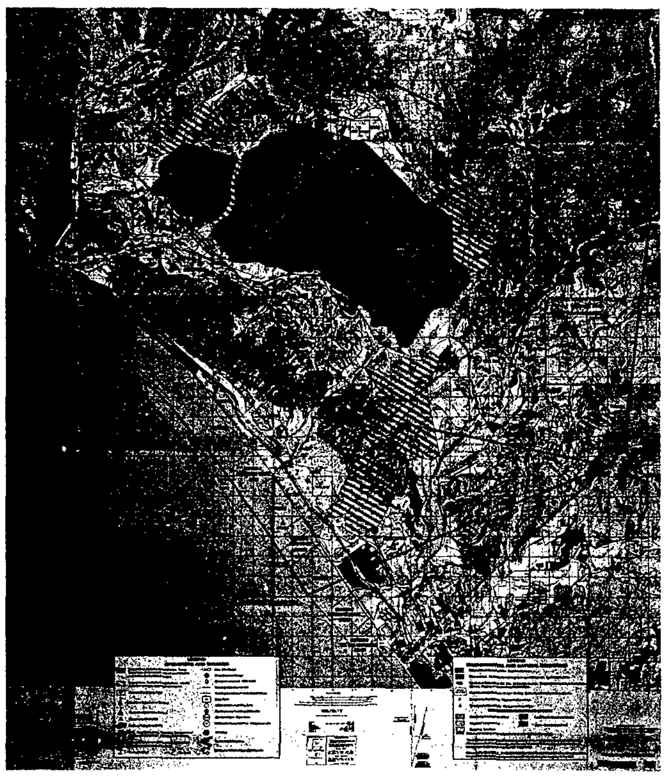

Figure 134

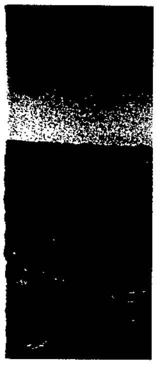

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Figure 134

The 'Camp Pendleton Special' map, produced by the U.S. Defense Map Agency (1994), shown in figure 134, is the land management map of MCB Camp Pendleton. The legend includes symbols for operations and training areas, including the impact zones which are shown in red. Perhaps less expected are the legend symbols for rare plant communities, vernal pools, and habitats of threatened and endangered species, such as the California gnatcatcher and least Bell's vireo. As noted in the beginning of this report, the property of the base is a totally managed landscape, and to date, it has been managed in an exemplary manner. It must be noted however, that this success is due, in part, to relatively sparse development in the surrounding area. In defining the future role of MCB Camp Pendleton in the management of regional biodiversity, a broader view must be taken.

This research has identified several future changes which affect the landscape of MCB Camp Pendleton across jurisdictional lines: scarcity of agricultural soils, change of soil moisture, increased flooding and stream discharge, fire management, maintenance of the natural landscape patches and connections to other major public lands, and habitat management for wide-ranging species.

In all of these, the relationship between the base and its regional context will be increasingly driven by new development in the surrounding region impacting the environmental systems on the base. One consequence will be increased pressure for environmental management on Camp Pendleton, and therefore potentially increased tension between the base's primary mission of training and habitat conservation objectives.

The lack of coordinated off-base landscape management for conservation and habitat protection, especially as these relate to developable land, may in the long run overwhelm Camp Pendleton's ability to manage for both training and habitat concerns. It is not a matter of quid-pro-quo with the region; it is a matter of lessening the impacts of off-base actions and inactions upon the base.

Two examples should suffice:

Camp Pendleton now has 23% of the region's gnatcatcher habitat. This will increase to about 35% at Build-Out, and will include about half the region's highest quality habitat. This increase is due to the lack of gnatcatcher habitat protection off-base.

Flooding on Camp Pendleton will double in the Santa Margarita watershed. For 1990+ it is estimated that a 25 year storm will have a peak discharge of $570m^3$/sec, and this will increase to $1050m^3$/sec peak discharge at Plans Build-Out. An *increase* of more than 107 million m^3 of total water discharge will be lost in one 25 year storm. This is because of new regional urban development off-base.

MCB Camp Pendleton can do little about the causes of these potential impacts as long as the towns and counties, which operate for civic purposes as separate entities, preceive and administer the cross-boundary ecological functions of the landscape as discrete local actions.

The surrounding jurisdictions will face increasingly complex development and conservation conflicts as large numbers of new residents locate to the area. Coordinating regional landscape planning will also require some changes in the definition of development; regional jurisdictions should recognize that the base is not an "open space," and that military manuever and impact areas are land uses.

MCB Camp Pendleton cannot be seen as an isolated property by either the region, its several jurisdictions, or the U.S. Marine Corps. From the perspective of this study, the base is wholly interdependent with its context. The activities on the base obviously impact the region economically, demographically and in other ways. At the same time the activities (and inactivities) of the region affect Camp Pendleton. This is especially the case when considering hydrological impacts on MCB Camp Pendleton caused by upstream development, fire management, the need to plan with nearby jurisdictions, and, as regional habitat declines, the increasing pressure on Camp Pendleton to manage its land both for an increased military training mission and for the maintenance of biodiversity.

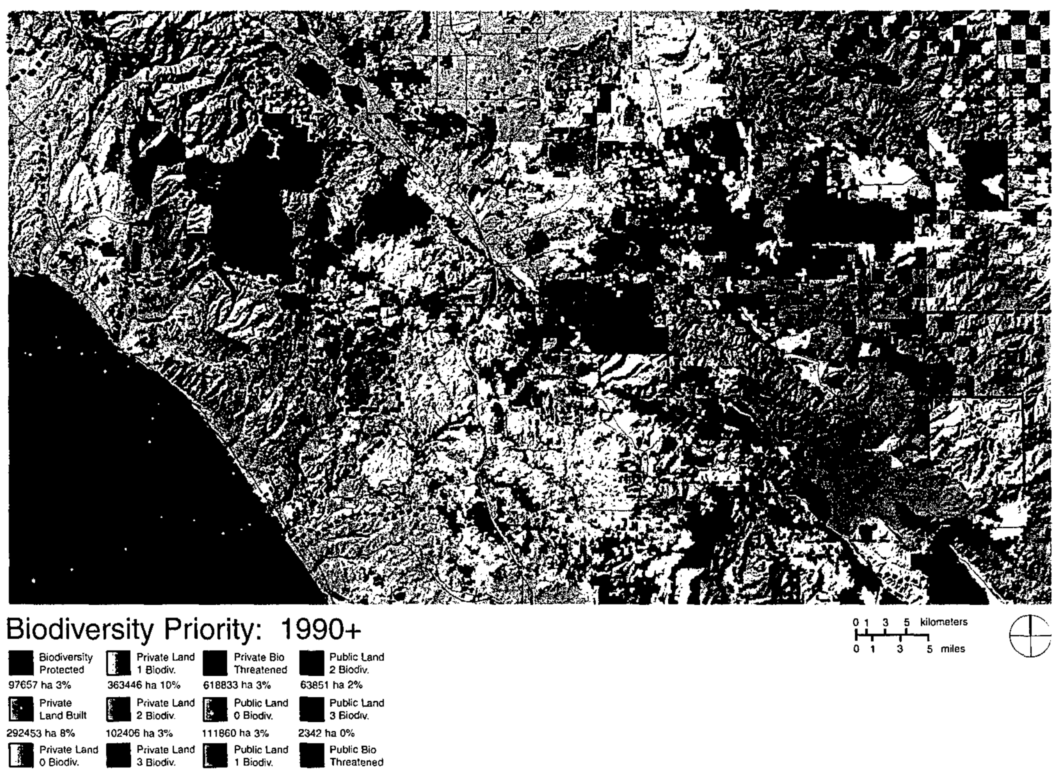
Conclusion

Some alternative conservation and development strategies should be seriously considered in the region and assessed more broadly for feasibility, in particular the **Private Conservation** strategy and the **Multi-Centers** approach. Special projects of regional significance should also be pursued, such as the wildlife connection across Interstate-15 and the designation of a regional scenic highway network.

There are critical locations in which projected development threatens the maintenance of biodiversity. Figure 135 shows areas of priority for landscape planning directed at the maintainance of regional biodiversity. These include GAPs in protection for species richness anticipated from **Plans Build-Out**, current core habitats for the several federally listed threatened species which were studied, and the most significant and the presently unprotected elements of the landscape ecological pattern (the large natural areas and their riparian corridor connections), with higher values assigned to increasing overlaps among the three measures of biodiversity. The highest priority is assigned to those priority public lands (in purple) and those priority privately owned areas (in red) which are currently unprotected and in which the vegetation habitat has been identified as at risk to the direct impacts of **Plans Build-Out** (figure 15) or the cumulated indirect impacts on vegetation (figure 46). Clearly, these are areas in which habitat management, conservation efforts, and sensitive site planning should be focused.

In a region where there is much rapid and decentralized change, and in which broader ecological consequences are seemingly not given much weight, there is every reason to be pessimistic

Figure 135



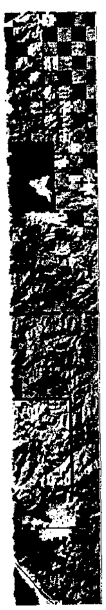


Figure 135

regarding future biodiversity. To change this, there are three decision-related conditions that must be met: the recognition of the values of biodiversity, the establishment of means to protect it, and the institutional changes needed to guide the development which will come to the region.

From the perspective of biodiversity, there will either be a gained opportunity, via careful regional planning and development and with selective conservation easements or acquisitions, or the considerable benefits of a multi-county, regionally linked landscape pattern will not be realized. Even the well-managed large natural areas such as the Cleveland National Forest, the East Side Reservoir Project zone, and MCB Camp Pendleton will become isolated "natural" fragments in an urbanized landscape matrix and much of their value for biodiversity will be lost.

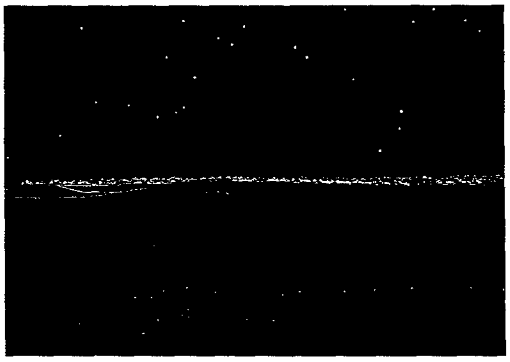
MCB Camp Pendleton's primary mission is the training of combat Marines, and its principal asset is the landscape. Degradation of the regional landscape may result in inferior training conditions. There is a clear need for the base to become more engaged in regional landscape planning, not only with San Diego County, within which it is located, but also with neighboring Orange and Riverside Counties. It can become a catalyst for regional landscape planning and management.

Unless biodiversity issues are included in the planning and implementation of future regional development, serious negative impacts will be seen both in the region and on the base. Thus, from the perspective of biodiversity, the interests of MCB Camp Pendleton and its regional jurisdictions are symbiotic, and their roles in the future management of biodiversity will require active partnership.

The long term implications of figure 133 present very complex and difficult choices. While the **Private Conservation** proposal seems the best alternative for protecting the region's biodiversity, it is likely to be very difficult to implement at the scale which is needed. Furthermore, it is not primarily directed at the efficiencies of urban development. In this respect, the **New City** and **Multi-Centers** alternatives are likely to be superior even though they are less effective in maintaining biodiversity. Also, while it might appear that the **Plans** and **Spread** alternatives are the easiest to implement and the most efficient from a development perspective, they will clearly be the worst for biodiversity. This situation presents a high risk dilemma: If the stakeholders of the region cannot move toward some combination of the alternatives which are better for biodiversity, there is every possiblity that the future will trend toward the worst, **Spread** development.

Timing is everything. Most of the long-term future pattern of biodiversity in the region will be set within the next fifteen years, and most development decisions which will shape that future will be made much sooner. When considering the magnitude, timing, and spatial implications of future regional development, only those policies which are implemented soon will be effective in maintaining the region's biodiversity.

The region of Camp Pendleton is fortunate that citizens and policy makers had the foresight to set aside the major public land holdings when they did. Future generations will measure today's actions by their environmental heritage. The window of need, and of opportunity, is *now*.



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Steinitz has devoted much of his academic and professional career to improving methods by which planners and designers analyze information about large land areas and make decisions about conservation and development. His teaching encompasses such courses as Theories and Methods of Landscape Planning and Visual Resource Analysis and Management. He has directed many landscape planning studies, most often of existing, highly valued landscapes that are undergoing substantial pressures for change. These have included Yosemite, Minuteman, Acadia and Gateway National Parks, the Gunnison region of Colorado, the Monadnock region of New Hampshire, the Park City area of Utah, and Monroe County, Pennsylvania.

Carl Steinitz has been the coordinator and editor of the research program. In addition, the alternative futures for the region of Camp Pendleton are the work of graduate students in his studio course, and the visual quality model results from his seminar.

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Binford received the M.S. in fisheries biology and experimental statistics from Louisiana State University and the Ph.D. in zoology and geology from Indiana University. He teaches courses in landscape and site ecology, principles of hydrology, and the ecology and restoration of wetlands, streams, and lakes. He also teaches and conducts research on ecological issues in developing nations.

Michael Binford is responsible for the hydrological aspects of the research.

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Paul Cote is a Geographic Information Systems Specialist at the Graduate School of Design, Harvard University. He is a cartographer who worked for Rand McNally and Simon and Schuster before joining the GSD.

Cote received the B.A. in Geography from Indiana University, and the Master in City Planning from the Massachusetts Institute of Technology. He teaches geographic informations systems and conducts developmental research in data management and cartography.

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Edwards has worked with a variety of sensitive and threatened and endangered species, including bald and golden eagles, ospreys, snowy plovers, and the Utah prairie dog. His current research interests include habitat needs for neotropical migrant birds and the development of methods for assessing and monitoring biological diversity at large landscape scales.

Thomas Edwards, with Kiester, is responsible for the models of species richness.

Stephen M. Ervin

Stephen Ervin is Director of Computer Resources at the Harvard Graduate School of Design. He teaches courses in landscape technology, landscape planning and design, and computer applications. Ervin received the Master in Landscape Architecture from the University of Massachusetts at Amherst and the Ph.D. from Massachusetts Institute of Technology.

Ervin has taught at the University of Massachusetts at Amherst and the Massachusetts Institute of Technology. He was the recipient of an Apple/ICEC fellowship at MIT. He has published research on computer-aided design and computer graphics applications. His research interests include design computing and the integration of geographic information systems in landscape architecture.

Stephen Ervin is responsible for the design and implementation of the computing infrastructure within which this study has been conducted.

Richard T. T. Forman

Richard Forman is Professor of Advanced Environmental Studies in the Field of Landscape Ecology at the Harvard Graduate School of Design. He teaches courses in natural systems and landscape ecology, which explore basic principles of structure, function, and change of landscapes.

Forman received the B.S. from Haverford College and the Ph.D. from the University of Pennsylvania. He has authored numerous articles and books, including *Landscape Ecology* (1986) with Michel Godron and *Land Mosaics* (1995), and coedited *Changing Landscapes* (1990) with I. Zonneveld. He has served as vice president of the Ecological Society of America and the International Association for Landscape Ecology. He currently studies boundaries, shapes, and corridors, models landscape change, and develops landscape ecology theory.

Richard Forman's theoretical approach is the basis of the analysis of the landscape ecological pattern.

Craig W. Johnson

Craig Johnson is Professor of Landscape Architecture and Environmental Planning at Utah State University. He received a B.L.A. degree from Michigan State University, an M.L.A. degree from the University of Illinois, and an M.S. degree in fisheries and wildlife biology from South Dakota State University.

He is a licensed landscape architect in the States of Idaho, Minnesota, and Utah, where he is actively involved as a design and planning consultant. Eleven of his projects have received state and national awards. Johnson has authored two books on urban forestry, one on land reclamation, and one on planning and design for urban wildlife. In 1988 he was recognized by Utah State University as Humanist of the Year, in part for his ongoing landscape restoration research on the Jordan River.

Craig Johnson is responsible for the single species habitat models, and the design plans for restoration of the sewage treatment ponds on Camp Pendleton.

Ross Kiester

Ross Kiester grew up in southern California not far from Camp Pendleton in the days when it was wonderful to be interested in herpetology. He attended the University of California at Berkeley, where he received his B.A. He completed his Ph.D. in Biology at Harvard University and was also a Junior Fellow at Harvard. He then taught at the University of Chicago and Tulane University before joining the USDA Forest Service.

Kiester has published on herpetology, biogeography, ecology, evolution, and the philosophy of science. He has also worked on planning issues in the Forest Service, including concepts of ecosystem management and the Tongass National Forest. Currently he is Team Leader of the Global Biological Diversity Team at the Pacific Northwest Research Station of the USDA Forest Service.

Ross Kiester, with Edwards, conducted the analyses of species richness.

David Mouat

David Mouat is on an Intergovernmental Personnel Agreement (IPA) assignment from the Desert Research Institute to the US Environmental Protection Agency, National Health and Environmental Effects Laboratory, Western Ecology Division, in Corvallis, Oregon. He manages the DoD Strategic Environmental Research and Development Program (SERDP) Project "Assessment and Management of Risks to Biodiversity and Habitat" and which included an element to develop methodologies to assess the impacts of potential land use scenarios on the biodiversity and related environmental aspects of military installations and their surrounding regions.

An Associate Research Professor at the Desert Research Institute, Mouat's primary research interests involve relating ecological characteristics, including vegetation composition and distribution, to issues of ecosystem health, land degradation, and environmental toxicity. Actively involved in desertification research, he has developed an integrated environmental assessment model for desertification evaluation. Mouat has been a research scientist at NASA, and has served on the faculties of the University of Arizona and Stanford. He received his Ph.D. in geography with an emphasis in geoecology from Oregon State University, and a B.A. in physical geography from the University of California at Berkeley.

David Mouat has been responsible for interagency aspects of the research program.

Douglas Olson

Douglas Olson is a principal in the Canadian firm of Olson+Olson Planning and Design. He holds a Doctor of Design degree in Landscape Planning from the Harvard University Graduate School of Design, a M.L.A. from the University of Manitoba, and a Diploma in Forest Technology. He is a visiting instructor at Harvard University as well an adjunct professor at the University of Calgary in the Faculty of Environmental Design.

A registered landscape architect, his recent projects include Adaptive Forest Management Planning for the Province of Alberta, the Landscape Plan for Jasper Townsite in Jasper National Park, Athabasca Park (Jasper National Park), and village and resort planning for the Ktunaxa/Kinbasket Tribal Council in British Columbia. His research activities include planning for agroforestry in Kenya and the use of airborne spectrographic imagers in landscape planning.

Among his several roles on the research team, Douglas Olson has been responsible for the spatial analysis of the landscape ecological pattern.

Allan Shearer

Allan Shearer is a Research Fellow at Harvard University. He received his A.B. from Princeton University and the M.L.A. from the Harvard University Graduate School of Design. He teaches the history of the American landscape at the Boston Architectural Center.

Prior to this study he worked as a landscape architect and contributed to projects including urban parks and campus master plans. He has received research grants to study fire manangement of prairie ecosystems and narrative methods for describing the landscape.

Allan Shearer was the "executive officer" on the research program and has participated in all aspects of the study. He was also the lead investigator in the Santa Rosa Plateau study with Harvard graduate students Jennifer Brooke, Hope Hasbrouck, Frank Kluber, and Debra Friedman.

Richard E. Toth

Richard Toth is Professor and Head of Landscape Architecture and Environmental Planning at Utah State University. He is a graduate of Michigan State University and Harvard University. Toth previously taught at the University of Pennsylvania and at Harvard. Toth has been active in professional practice for many years in both Canada and the United States. He is a licensed landscape architect in Utah, Idaho, and Massachusetts.

Toth's research activities focus upon landscape analysis. He pioneered several landscape planning approaches which have integrated design development with ecologically driven conservation goals. His current research interests maintain this conceptual integration and have focused on hydrologic and riparian systems.

Richard Toth directed the "Oak Grove" studies which are the work of graduate students in his studio course.

Graduate Student Authors,

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Jill Schroeder
Todd Sherman

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Contributing Faculty: John Nicholson, David Bell, James MacMahon, Michael Wolfe
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Robin Wills

Robin Wills plans and implements fire management activities for the California Nature Conservancy. His research focuses on applied fire research in grasslands and coastal sage scrub vegetation types.

Wills received a B.S. in forest biology from the Ohio State University and a M.S. in forest ecology from Humboldt State University, California. He spent six years in fire suppression and management with several federal and state agencies and three years with the USDA Forest Service in research on fire effects in Mediterranean plant communities.

Robin Wills is responsible for the fire models.

Picture Credits

p. 58 Arroyo Southwestern Toad
Richard G. Zweifel, in Behler and King (1995)

p.60 Orange-Throated Whiptail Lizard
R.S. Funk, in Behler and King (1995)

P.62 Coastal Cactus Wren
Jeff Foott, in Udvardy and Farrand (1994)

p.64 Least Bell's Vireo
Todd Fink / Daybreak Imagery in Udvardy and Farrand (1994)

p.66 California Gnatcatcher
B. "Moose" Peterson in Taylor (1994)

p.68 Western Bluebird
Tim Zurowski, in Udvardy and Farrand (1994)

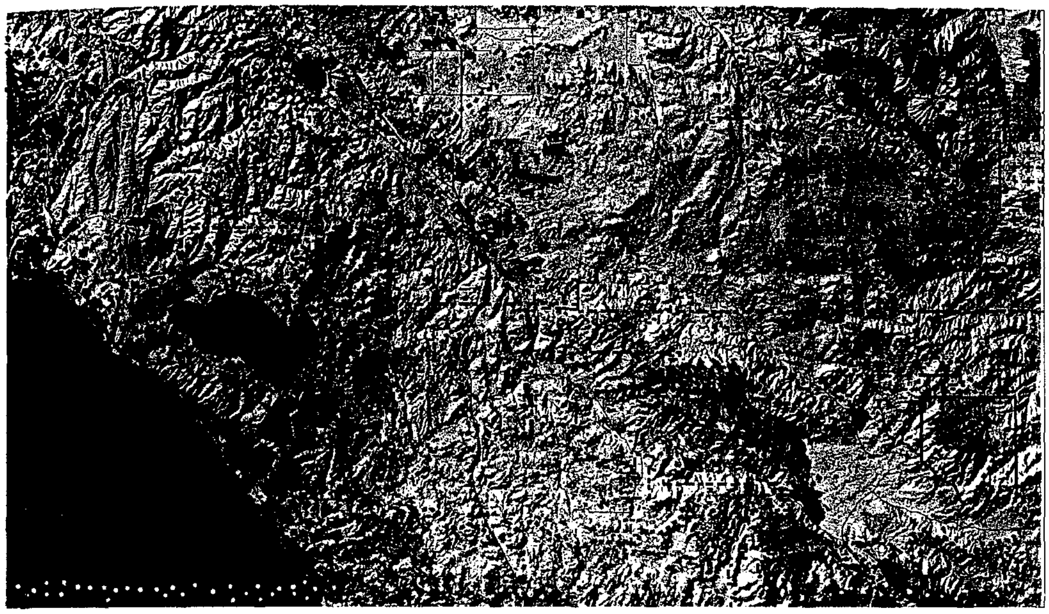
p.70 Brown Headed Cowbird
Robert C. Simpson, in Udvardy and Farrand (1994)

p.72 Gray Fox
Wayne Alcord, Zion National Park Photo

p.74 Mule Deer
Victor Jackson, Zion National Park Photo

p.76 California Cougar
Dale Smith, Zion National Park Photo

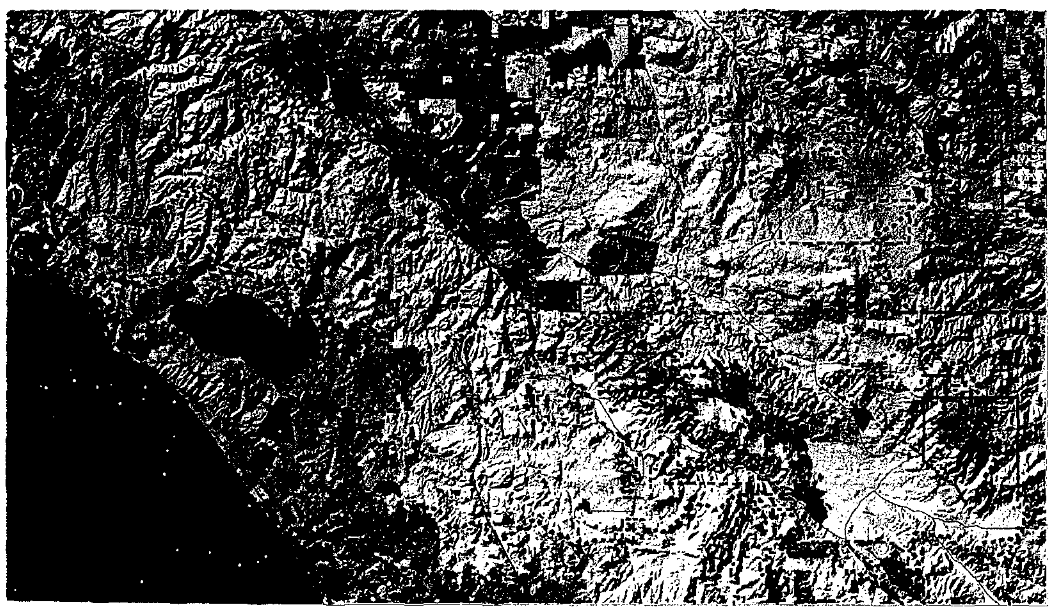
This publication was designed, edited and produced by Carl Steinitz, Allan Shearer, Douglas Olson, Stephen Ervin, Irene Fairley, Ross Keister, David Mouat, Nancy Levinson, and Susan McNally.



Land Cover: 1990+

0 1 3 5 kilometers
0 1 3 5 miles

Water	Mixed Forest 147617 ha 4% ha	Grasslands 168775 ha 5%	Single Family Res 79521 ha 2%	Military Impact 50221 ha 1%
Riparian Vegetation 21051 ha 1%	Orchards 79808 ha 2%	Altered Land 161655 ha 5%	Multi Family Residential 90344 ha 3%	Commercial Industrial 86848 ha 2%
Oak Woodland 131095 ha 4%	Sage, Chaparral 1640626 ha 46%	Rural Residential 276226% 8%	Military Maneuvers 117124 ha 3%	Trans-portation 14105 ha 0%



Land Cover: Plans Build-Out

0 1 3 5 kilometers
0 1 3 5 miles

Water	Mixed Forest 96610 ha 3%	Grassland 82780 ha 2%	Single Family Res 304038 ha 9%	Military Impact 49981 ha 1%
Riparian Vegetation 11453 ha 0%	Orchards 3887 ha 0%	Altered Land 67463 ha 2%	Multi Family Residential 110903 ha 3%	Commercial Industrial 155939 ha 4%
Oak Woodland 56713 ha 2%	Sage, Chaparral 1080648 ha 30%	Rural Residential 906378 ha 25%	Military Maneuvers 116374 ha 3%	Trans-portation 165638 ha 0%